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November 30th, 1946
Telephone Number TUcker 2571

Washington Highlights

Independent petroleum specialists iew with favor a plan whereby the avy will assume two-thirds of the ost of maintaining its Elk Hills oil eserve. Standard Oil Co. of Calif. ow bears the full expense of keepg the reserve in readiness, under contract with the Navy.

These specialists were called for onsultation by the House Naval ommittee Counsel at the suggesion of Secretary of the Navy Forestal. At a hearing last Septemer on he proposed contract amendment between Standard and the Navy, Forrestal requested permission to call independent oil leaders for their opinion as to the equity f the arrangement.

At a press conference, Gerald D. Morgan, special counsel for the committee, disclosed that the experts greed that the amendment was minently fair. It would require the avy to pay two-thirds of the mainenance expense, and Standard onehird, which would amount to about 400,000 and $200,000 a year, respectively.

* * *

Paul L. Kleinsurge, chairman, as announced that the 10 Regional Vage Stabilization Boards will erminate all enforcement activity n January 15. The new executive rder, which removed wage and salry controls, provides that any payent of excessive wage rates made rior to November 9 will be subct to enforcement action. Cases hich may be pending after that ate probably will be delegated to he Bureau of Internal Revenue or ther Federal agencies.

An oil school for advanced Army officers will start early in January at Camp Lee, Virginia. The curriculum will be world reserves, military and civilian oil picture, processes and technique, requisition methods, and distribution from the United States for overseas bases, according to the War Department. Also for consideration will be foreign policies of the State Department and the Army-Navy Petroleum Board.

* * *

The Independent Petroleum Association of America has petitioned Congress to limit the jurisdiction of the Federal Power Commission. The IPAA asked Congress to amend the natural gas act so as to deny the FPC authority to govern the production or gathering of natural gas, price of gas sold by producers or gatherers, or end use of gas.

* * *

The shortage of steel remains a chief problem in the nation's capital. Consumers' stock of both iron and steel scrap decreased to 2,900,000 tons at the end of August. This is less than a month's supply for the steel industry, which depends upon scrap for approximately 50 per cent of its material for steel making. As compared with the preceding month, the stock decline was 368,000 tons.

The oil industry has been particularly hard hit by the scarcity of steel, particularly in the field, where countless drilling projects are delayed at various stages, or in many instances not even started, due to lack of casing and pipe.

Washington headquarters of the Department of Commerce announced the opening of a regional office in the Federal Post Office Building at Los Angeles. All of Southern California as well as the entire state of Arizona makes up the region. California counties included in the region are Kern, San Luis Obispo, Santa Barbara, Ventura, Los Angeles, Riverside, Orange, Imperial, San Diego and San Bernardino.

* * *

A House committee has launched an investigation into the proposed disposal by the Government of the famed warborn "Big Inch" and "Little Inch" pipelines. Chairman Slaughter, Democrat of Missouri, said the committee seeks determination as to how the best interests of the entire country may be served in disposing of the lines to private owners.

* * *

In a move designed to unify oil and gas policy and administration, a preliminary survey is being carried on among 31 Federal agencies to analyze and evaluate the functions they perform as relates to oil and gas, according to an announcement by Secretary of the Interior Krug.

* * *

A winner in the House of the Republicans in Detroit's 13th district was jovial Howard A. Coffin, general manager of the White Star Division of Socony-Vacuum Oil Co.

Mr. Hoge goes to TEXAS

FRIDAY: Houdry Laboratories receive a long distance call from a Texas refinery, requesting assistance in the operation of a TCC unit. Wesley Hoge, able Houdry engineer, leaves by train the next day. (He would have flown but all planes were grounded.)

TUESDAY A. M.: Mr. Hoge arrives at the refinery, confers with Houdry's Texas representative and refinery management; then inspects unit.

THURSDAY NOON: At Hoge's suggestion, unit is shut down to permit examination of the reactor.

THURSDAY MIDNIGHT: Twelve hours after shut-down began, inspection of the reactor has been completed, mechanical adjustments made per Hoge's recommendations, and unit is ready to resume operation. Pretty good time, even for a TCC!

FRIDAY: Unit is operating at rated capacity and producing 1,000 B/D *more gasoline* than prior to shut-down. Mr. Hoge takes a bow but not his departure—he stays right there to make sure the operation stays right.

TWO WEEKS LATER: Even Mr. Hoge is satisfied and leaves for home. Refinery executives write nice letters to Houdry. It's really nothing extraordinary, just typical of the kind of service Houdry gives its licensees.

Houdry service begins with the blueprints and never ends!

HOUDRY PROCESS CORPORATION

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HOUDRY CATALYTIC PROCESSES

Delayed Coking Unit at the General Petroleum Torrance Refinery

By
Randal Maass
R. E. Lauterbach

INTRODUCTION

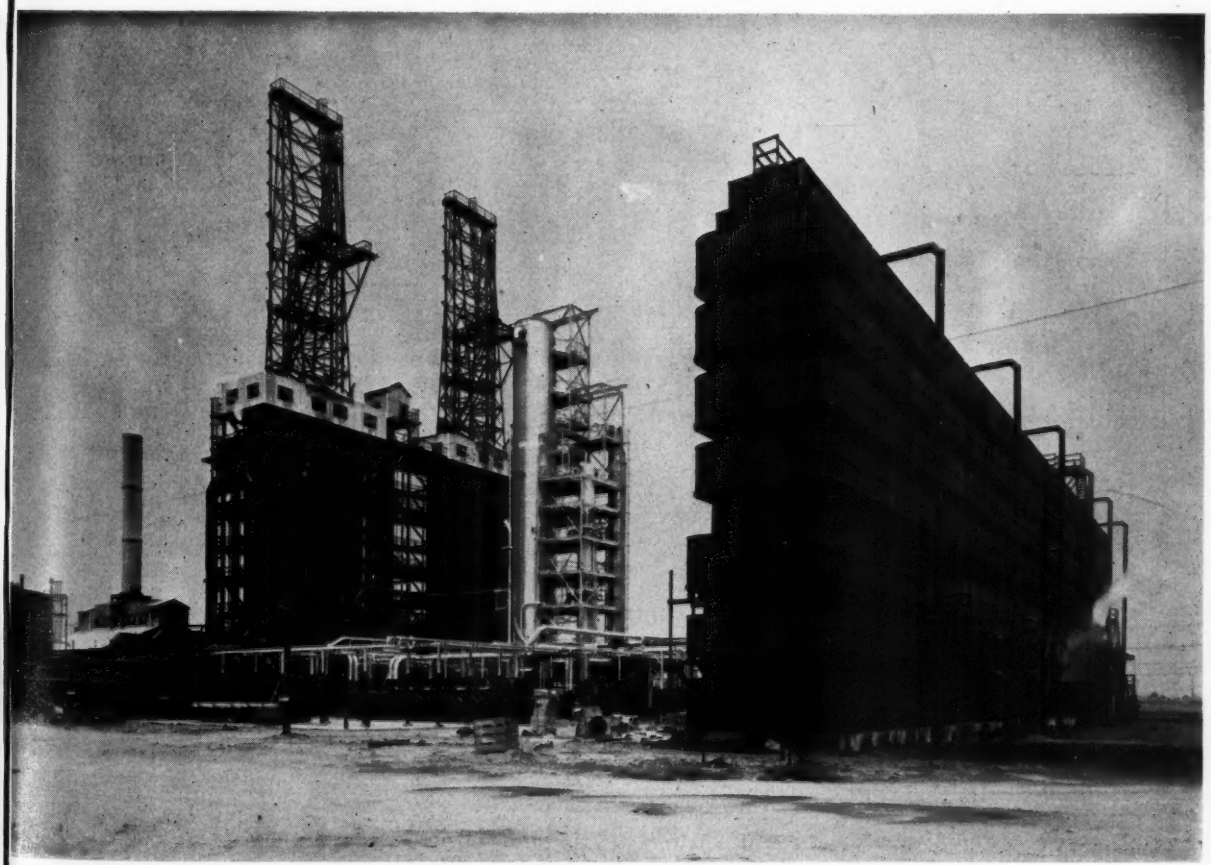
With the Diesel engine, the household burner, and the light oil cracking units all competing for the intermediate or gas oil fractions, the general trend in refining is toward a more extensive cracking of the residuum fraction. It has been estimated that this trend, in the next 10 to 20 years, will reduce the percentage residuum from the present 26% to some 10%. It is not expected that this cracking of heavier stock will so much replace light oil cracking as that it will provide the requisite charge stock.

The General Petroleum Corporation has contributed to this trend by installing a 15,000 B/D Delayed Coking Unit to process 300"-700" SSF/122°F straight run residuum. The gas oil thereby obtained will serve to supply part of the feed stock to the four TCC Units. The Coking Unit was designed, engineered, and constructed by the M. W. Kellogg Company, and incidentally is the largest unit of its kind in the world. Coking operations were started July 26, 1946, culminating a successful and relatively simple startup operation.

It is the intent of this paper to describe the Coking process with particular emphasis on the equipment used therein. Some of the initial operating data too has been added.

GENERAL PROCESS

The description of the general process may best be followed by referring to the Flow Sheet, Figure I. The cracking portion of the Coking Unit is divided into two sections each with its own furnace and pair of coke drums to be used alternately. The cracked products from the two cracking sections enter a common bubble tower for fractionation into an overhead product of gasoline and lighter, three gas oil draw products, and a bottoms recycle product. The straight run residuum charge, or reduced crude charge as it is also called, is introduced into the bubble tower for further fractionation with the bulk of it appearing in the bottoms for furnace charge. Three steam strippers for the sidedraw streams and a gasoline debutanizer complete the fractionation equipment.



General view of Coker Unit with north furnace hidden behind coke drums.

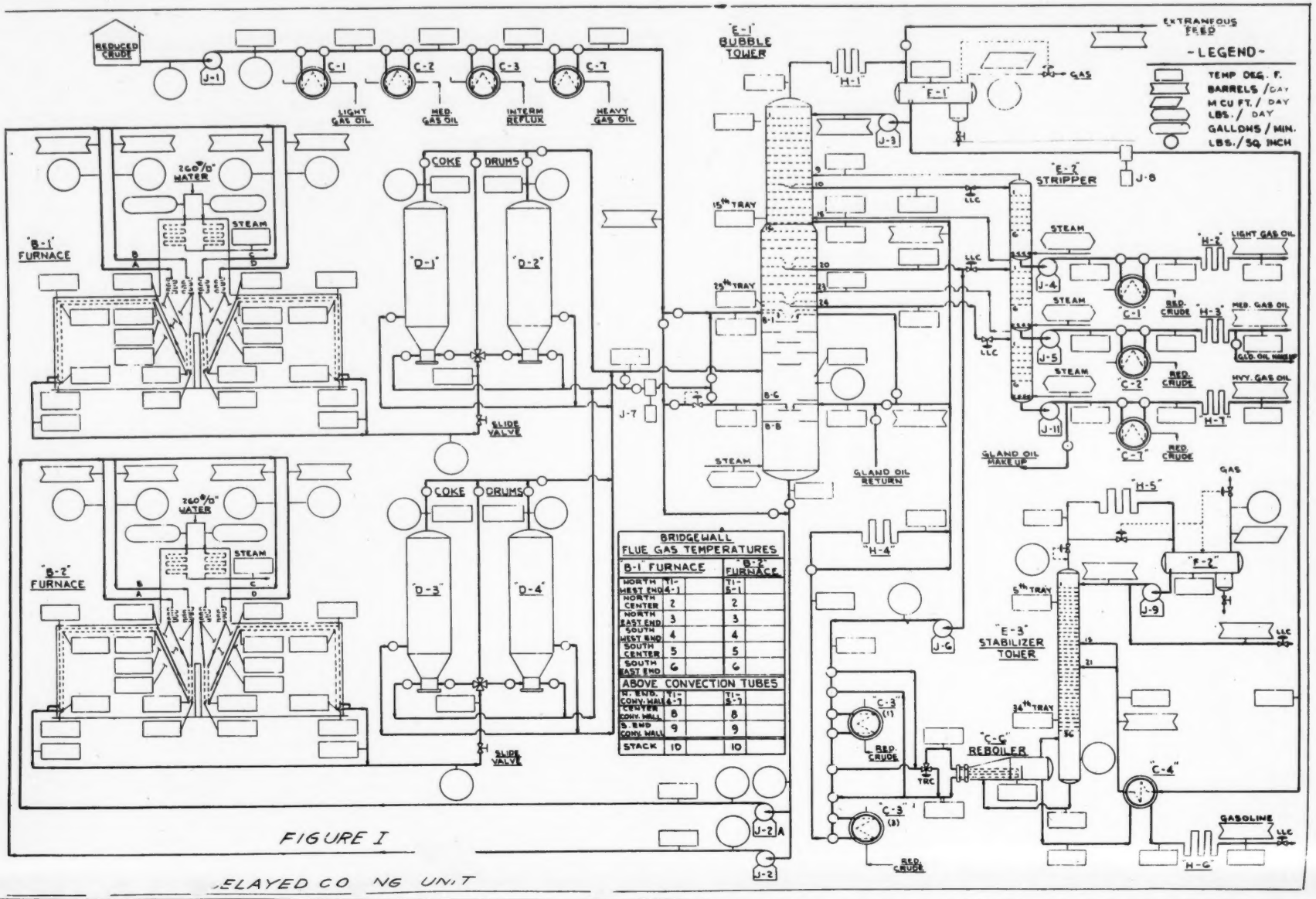


FIGURE I

DELAYED CO ING UNIT

PHYSICAL EQUIPMENT

Furnaces

As was indicated above, two duplicate furnaces have been provided, one for each pair of coke drums. The distinguishing and highly desirable feature of a delayed coking unit is the delaying of the coking until the charge reaches the soaking chamber (coke drum). To accomplish this the furnaces are designed for a low residence time and consequently a high rate of heat pickup. Because of the high heat level (600°F) of the furnace charge, the oil tubes were restricted to the radiant section and the hotter portion of the convection section. Heat economy is realized through the use of water tubes for steam production in the colder portion of the convection bank.

In general each furnace has four separate coils which join outside the firebox into a common transfer line. The 3-¼″ O. D. tubes are 42′ long and have a wall thickness of 7/16″. Alloy tubes of 9 chrome—1.5 moly are used in the radiant section and to shield the convection bank. The remaining tubes in the convection bank are 5 chrome—0.5 moly. Heat is supplied by 16 Zink combination oil and gas burners located in the end of the firebox.

Waste Heat Boiler

As was indicated above, the temperature of the furnace charge was too high to realize a good heat economy with oil tubes alone. Therefore, a waste heat boiler, with its lower receiving temperature, has been added in the convection bank of each furnace to reduce the temperature of the flue gases. This heat pickup serves to supply some 75% of the plant's steam requirement. The outlet of the coils from the two furnaces enter a common steam drum from which a single boiler feed pump takes suction to circulate the water through both coils. A level control maintains the water level in the drum by admitting treated water from the refinery main boiler plant feed pumps.

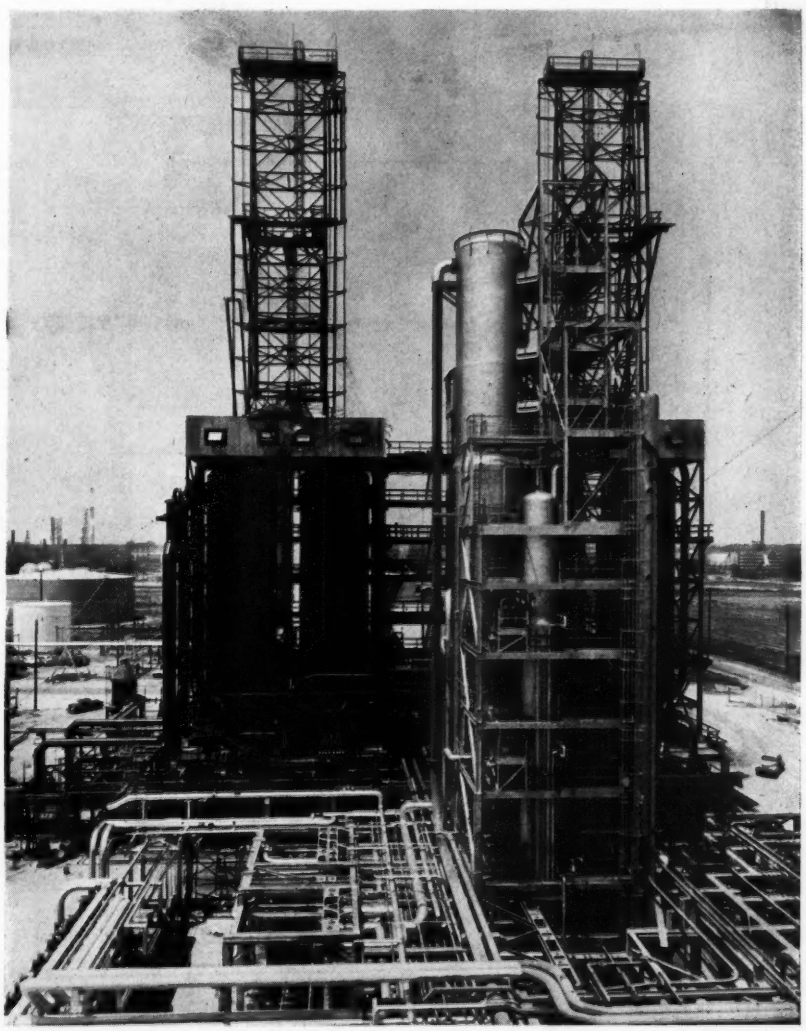
Coke Drums

A continuity of operation is maintained through the use of a pair of coke drums for each furnace, one drum being in coking service while the other is being decoked. Each drum is 17′ in diameter and 80′ in height with 61′ of straight section. For protection against corrosion the vessels are lined with a 7/64″ thickness of Type 405 stainless steel, the lining being resistance welded to the shell. In addition the upper half of the shell is ⅞″ thick and the bottom half 1″ thick. To subject a vessel of this size to the changing temperatures of blocked operations requires, of course, that it be fully stress relieved and its welds x-rayed.

Alloy steels were also used in the principal piping to and from the Coke drums. The transfer lines were fabricated from 9 chrome—1 moly pipe and the vapor lines from the drums to the bubble tower from 5 chrome—0.5 moly. Portions of the drum condensate lines, the side vapor lines, and the by-pass lines are also of alloy steel.

Bubble Tower

The 100′ high bubble tower is 11′ in diameter in its upper section and in its bottom section is enlarged to 12′6″ to accommodate the increased downflow occasioned by the introduction of the intermediate reflux and the reduced crude feed. Fifteen cast iron bubble trays are used in the upper section and in the lower section ten Type 405 stainless steel bubble trays with eight cast iron baffle trays below them in the potential coking region. The shell thickness varies from 9/16″ to 15/16″ and is protected throughout by a 7/64″ Type 405 stainless steel strip-welded lining.



View of south pair of coke drums showing drilling equipment for decoking above. Distillation columns in right foreground.

FIGURE III
HYDRAULIC CONVEYING SYSTEM
Schematic Arrangement of
COKE HANDLING SYSTEM
WORTHINGTON PUMP AND MACHINERY CORPORATION
HARRISON, NEW JERSEY

To reduce construction costs the three sidedraw steam strippers are contained in one 4'6" by 56' shell appropriately divided into three 6 bubble tray sections. The available hydrostatic heads dictate that the strippers be used in the same vertical order as the draw; that is, with the top draw in the top stripper, etc. The strippers are unlined and the trays are all cast iron.

It will be noted that the entire hot oil section of the plant is protected from corrosion through the use of alloy steels. In the bubble tower region, however, some exceptions were made after considering the corrosion tendency and ease of replacement.

Debutanizer

The design of the 4', 36 bubble tray debutanizer follows the conventional pattern. The tower is unlined and all trays are cast iron. To accommodate possible depropanization, the design working pressure was set at 330 psi.

Heat Exchange Equipment

Some characteristics of the shell and tube heat exchangers are tabulated below.

Decoking Equipment

Coke is removed from the drums by a water jet designed by the Worthington Pump and Machinery Corporation, which cuts the body of coke into pieces small enough to fall into a crusher car. The crusher car breaks the pieces of coke down to a maximum dimension of 5 inches and feeds the sized coke into a sluice. The coke is sluiced with water into a suction pit from which a coke-water slurry is pumped through a 12" line to the storage area. In this area the bulk of the coke is separated from the water and is moved to a convenient location for shipping. The water passes through settling basins to allow any coke fines to drop out and is then returned to the unit for re-use. A schematic diagram of the coke handling system is shown in Figure III.

The decoking water jet is supplied by a centrifugal five stage volute pump with external interstage passages. An hydraulically balanced rotor was obtained by providing double inlets at the first stage and by placing the remaining four single inlet stages back to back. The double inlet at the first stage also provides a low inlet velocity which permits operation at a low submergence. All impellers are of the enclosed type. A pressure breakdown bushing is provided at the inboard stuffing box so that both stuffing boxes are under suction pressure. The 4,000 r.p.m., 1,450 horespower turbine drive is supplied with 165 lbs., 100°F superheated steam and exhausts to a 26" Hg. vacuum provided by a barometric condenser. Two complete pumping units are provided; one will supply 1,000 g.p.m., at 1,500 lbs.; two in parallel will supply 1,600 g.p.m. at the same pressure. Electrically powered block valves located in the discharge line, operate so as to prevent a shut-off against the pump. When the main block valve begins to close a smaller bypass valve begins to open so as to discharge the water back to the suction tank. In reverse the valve operation affords the same protection. From the pump discharge the jet water flows to a manifold at the top of the coke drum.

A 100 ft. derrick structure is mounted over each pair of coke drums to support the drilling equipment. Each drilling assembly includes a continuous length of drill stem which is long enough to reach the whole length of the drum and to which the boring and cutting tools can be attached. The drill stem is coupled at the top to a swivel head which is rotated by an air motor and which can be raised or lowered by a steam winch. An assembly of Chiksan joints form a flexible connection to supply jet water to the swivel head. Block valves have been provided in the jet water lines to each drilling assembly. These valves are closed whenever the drill stem is removed from the drum so that no one would be injured if the high pressure water were inadvertently turned on.

The cutting devices for removing coke are a boring tool, a reaming tool, and a cutting tool. The boring head which is illustrated in Figure IV is essentially a round ball about 10" in diameter which is tapped for water nozzles. One ½" nozzle is located in the bottom to direct a jet straight downward, and four ⅜" jets are symmetrically arranged

HEAT EXCHANGERS

Shell Side	Tube Side	No. of Bundles	Total Surface Sq. Ft.	Tube Material
Reduced Crude	Light Gas Oil	2	2,480	Steel
Reduced Crude	Heavy Gas Oil	2	2,480	Steel
Reduced Crude	Intermed. Reflux	4	12,880	Steel
Reduced Crude	Fuel Oil	2	4,350	Steel
Stabilized Gasoline	Stabilizer Feed	2	1,090	Steel
Stabilizer Bottoms (Stabilizer Reboiler)	Intermed. Reflux	1	2,000	Steel

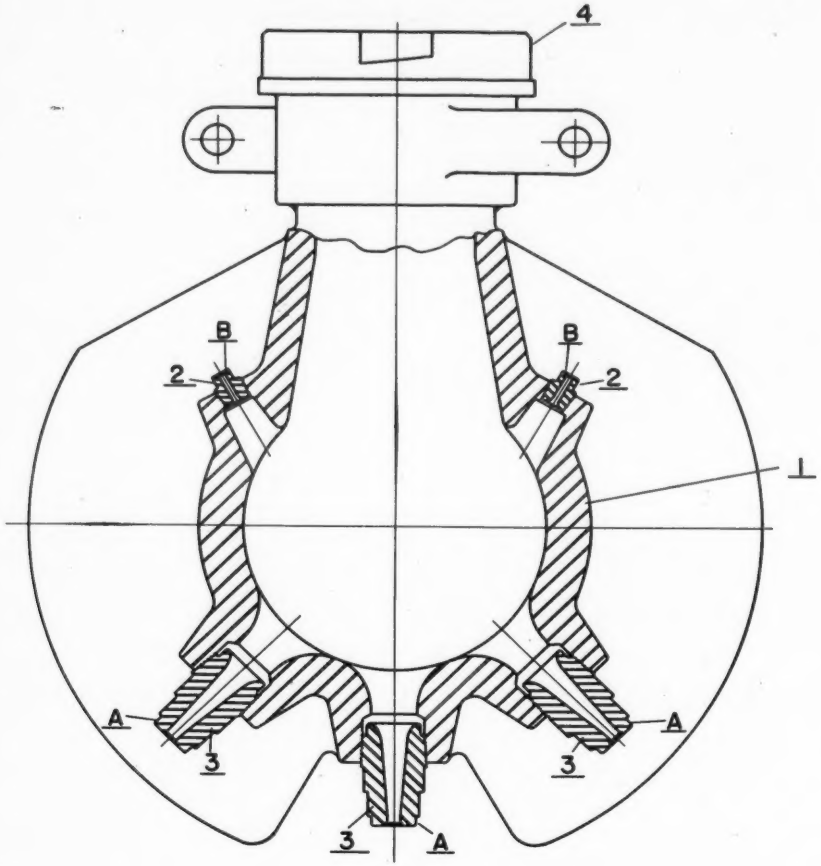
Following our general practice open section condensing and cooling equipment is used throughout. Open section, located in a 45 bay atmospheric cooling tower, were provided as follows:

CONDENSERS & COOLERS

Service	No. of Bundles	Total Surface Sq. Ft.	Tube Material
Bubble Tower Overhead	18	10,200	Admiralty Brass
Light Gas Oil	4	2,020	Admiralty Brass
Heavy Gas Oil	6	3,030	Red Brass Clad Steel
Intermediate Reflux	2	1,140	Admiralty Brass
Stabilizer Overhead	4	2,280	Admiralty Brass
Stabilizer Bottoms	1	530	Admiralty Brass
Fuel Oil	8	4,660	Red Brass Clad Steel
Gland Oil	2	1,060	Admiralty Brass
Gland Water	2	1,140	Admiralty Brass

8L206-XC

PART NO.	NO. OF PCS PER UNIT	NAME OF PART	MAT'L	PATT. NO.



PART #	NAME OF PART
1	FIRST BORING TOOL - COMPLETE
2	CLEAN-OUT NOZZLES
3	BORING NOZZLES
4	UNIBOLT COUPLING - LOWER HALF

FIGURE IV

PLEASE NOTE

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61—Smooth	"
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Tolerances for detail drawings
Finished fractional dimensions where no batch given ± 64
Decimal ± .005
Where closer tolerances required limits are specified.
This note does not apply to Elevations or Test Slips

HYDRAULIC DECOKING SYSTEM
FIRST BORING TOOL ASSEMBLY

WORTHINGTON PUMP AND MACHINERY CORPORATION
HARRISON, NEW JERSEY

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about it to direct the water downward at about 45° from the vertical. Two 1/8" jets are directed upward to keep any coke fines from settling on top of the tool and stopping its rotation.

For reaming, the same tool is used, except that the bottom jet is removed and plugged off, and the four 3/8" nozzles are replaced with 1/2" nozzles.

The cutting tool shown in Figure V is an hydraulically designed assembly which splits the single stream of water in the drill stem into four jet streams. Two streams are projected horizontally at the top of the tool and the other two at the bottom are directed upward at such an angle that they cut the same plane as the horizontal jets at the surface of the coke drum, or at a distance of 8½ feet from the axis of the drum. The nozzle tips in this tool are replaceable and at the present time 5/8" tips are used in the bottom nozzles while 7/16" tips are used in the top.

The crusher car, which grinds the coke to a size easily pumpable by the coke pump, consists of an 11x14 ft. hopper which feeds the coke to two 2 ft. dia. by 5 ft. long toothed rolls spaced 5" apart. The rolls are driven by a 40 horsepower motor. The crusher car is mounted on wheels and a track so that it can be positioned beneath any of the four drums. A "grizzly," fabricated of 1"x8" plate, has been added near the top of the hopper to keep any large chunks from bridging over the crusher rolls or damaging them by impact.

The crushed coke and the water from the jets pass between the rolls into a sluice which leads to a coke sump. Additional sluice water is added to the ditch as needed to keep the coke and water from piling up under the crusher car. An Allen-Sherman-Hoff Hydroseal coke slurry pump, located in a pit adjoining the coke sump, pumps the coke-water slurry through a 12" line to the coke storage area located some 2,500 feet from the pump. The pump derives its name from the clean water supplied to the case to seal the impeller. This water also serves to flush grit away from the close clearance area between the impeller shrouds, shaft, and suction eye and the rubber lining provided in that area. The speed of rotation of the pump can be varied by means of an adjustable sheave on the motor and three sizes of sheaves on the pump. At 600 r.p.m. the pump will discharge about 3,000 g.p.m. of water over a coke outlet some 38 ft. above its suction nozzle through 2,500 ft. of 12" line.

Special hydraulic lift cars were designed to raise and lower the heavy bottom heads of the coke drums. Had only one car been provided, the track system would have been needlessly complicated to permit moving one car past the other. This complication was avoided by providing cars to be placed on the single track on both sides of the crusher car. Also, with two cars, two drum heads can be worked on at the same time. The hydraulic lifts operate on 90 lbs. water and are individually capable of supporting the bottom head plus the drum height of water.

This brief description of the principal process equipment should serve to clarify the following discussion of the unit operation. Additional equipment description will be included in the discussion.

OPERATION OF THE UNIT

Feed Introduction

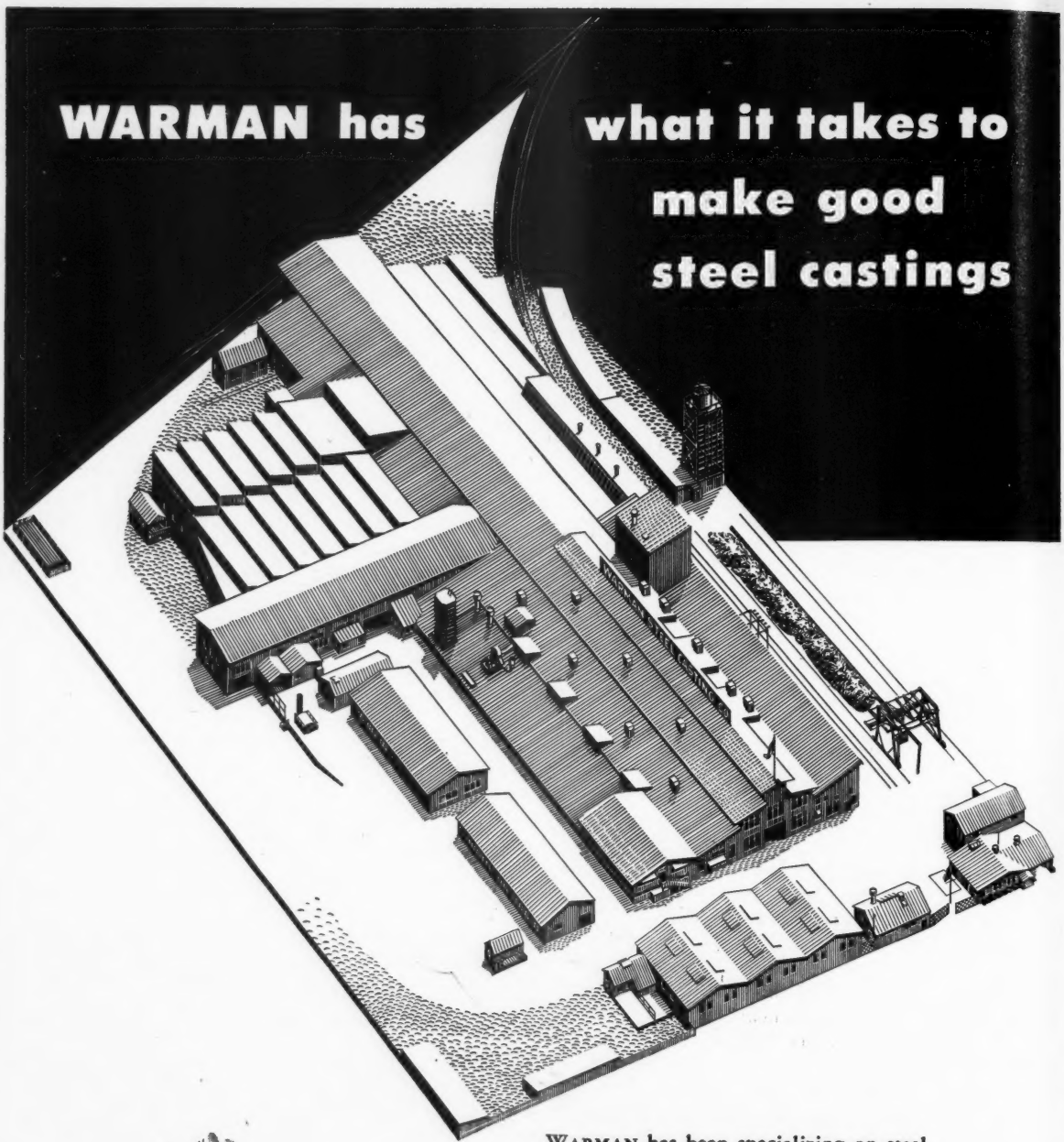
Reduced crude is charged to the bubble tower by Quimby screw-type charge pumps under control of a flow-controller which regulates the rate by positioning a by-pass valve between the pump discharge and suction. The reduced crude is preheated by exchange successively with the light gas oil product, the medium gas oil product, the intermediate reflux stream, and the heavy gas oil product before entering the bubble tower at two points, at the top baffle tray or five baffle trays above the cracked vapor inlet and at the second baffle tray from the bottom or two baffle trays below the cracked vapor inlet. With a preheat level of only 450°F the feed serves as a hot reflux and care must be exercised to avoid transferring so much heat to the tower bottom product, through a contact with the cracked vapors (the sole source of fractionating heat), as to impair the fractionation of the tower. This condition is avoided by temperature controlling the flow of reduced crude to the top inlet so as to maintain a constant temperature on the bottom bubble tray. The excess feed is diverted by a pressure controller to the lower inlet. Any feed thus diverted also serves to subcool the tower bottom and thereby reduces the tendency to form coke in this reservoir.

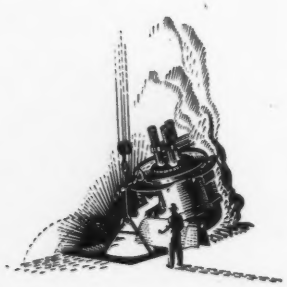
Heating

Both furnace charge pumps take suction off the tower bottom to deliver the charge to the four paral-

Row of B-B Sphere Storage.

WARMAN has what it takes to make good steel castings





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lel coils in each furnace. The radiant section of each furnace is divided into two combustion chambers containing two of the coils. The charge flow is rate controlled to each half of the furnace and the fires in each combustion chamber are separately controlled to maintain a constant temperature at the combined outlet of each pair of coils. The two temperature controlled outlets from each furnace join in a furnace transfer line which discharges into one of the two coke drums allocated to each furnace.

Coking

The heated mixture of vapor and liquid from the furnace enters the bottom of the coke drum. Since only vapors can pass out the top of the drum, any liquid must remain in the drum until it is cracked to vapors and coke. As coke is deposited the incoming liquid and vapor must flow through the coke bed and through or into the liquid on top of the coke. With vapors and liquid continually flowing through the coking region, the coke deposited is of a highly porous nature, which facilitates subsequent handling and contributes to the quality of the product. Each drum remains on the line for 24 hours during which time approximately 250 tons are therein deposited.

Fractionation

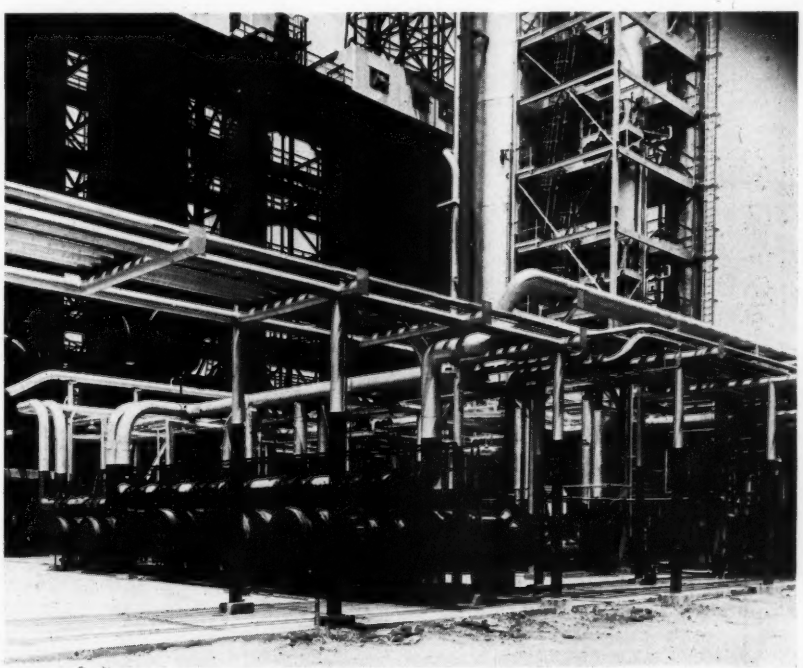
The vapors from the two drums currently in simultaneous operation enter the bubble tower between the 5th and 6th baffle trays, numbering from the top. As previously mentioned this stream supplies the sole source of fractionating heat to the tower. The top temperature of the tower is controlled, by means of vaporizing reflux, to pass the gasoline and lighter streams overhead. A portion of the downflow induced by the top reflux is removed from the 10th bubble tray, steam stripped, and delivered to storage, after heat exchange and cooling, as light gas oil. The remaining downflow is augmented at the 15th bubble tray by an intermediate reflux stream and by the additional reflux thereby induced. To handle this additional flow the tower is enlarged at the 15th tray from 11 ft. to 12 ft., 6 in. in diameter. The intermediate reflux is removed from the 20th bubble tray to be cooled by heat exchange with the fresh feed, by supplying heat to the debutanizer reboiler, and by exchange with cooling water if necessary. The intermediate reflux returned to 15th tray is rate controlled. Should it be desirable to reduce the down flow on the lower bubble trays some intermediate reflux can be manually controlled to the 1st baffle tray. As an added means of reducing the coking tendency in the bottom two baffle trays and the tower bottom reservoir, provision has been made to manually control some of this reflux to the 7th baffle tray if needed. The intermediate reflux draw is also used to remove the medium gas oil product which is stripped and cooled. The heavy gas oil, which is also stripped and cooled, is withdrawn from the 24th bubble tray.

The preheated fresh feed is added to the 1st baffle tray as required to maintain a constant temperature on the 25th or bottom bubble tray, the remaining feed being diverted to the 7th baffle tray. The tower bottoms, which include the fresh feed and recycle, are rate controlled to the furnaces. The lowest sidedraw is withdrawn at rate required to maintain the tower bottom level. Under this arrangement, with a constant 20,000 B/D charge to the furnaces, the recycle rate is automatically determined as the difference between the fresh feed rate and the total furnace charge.

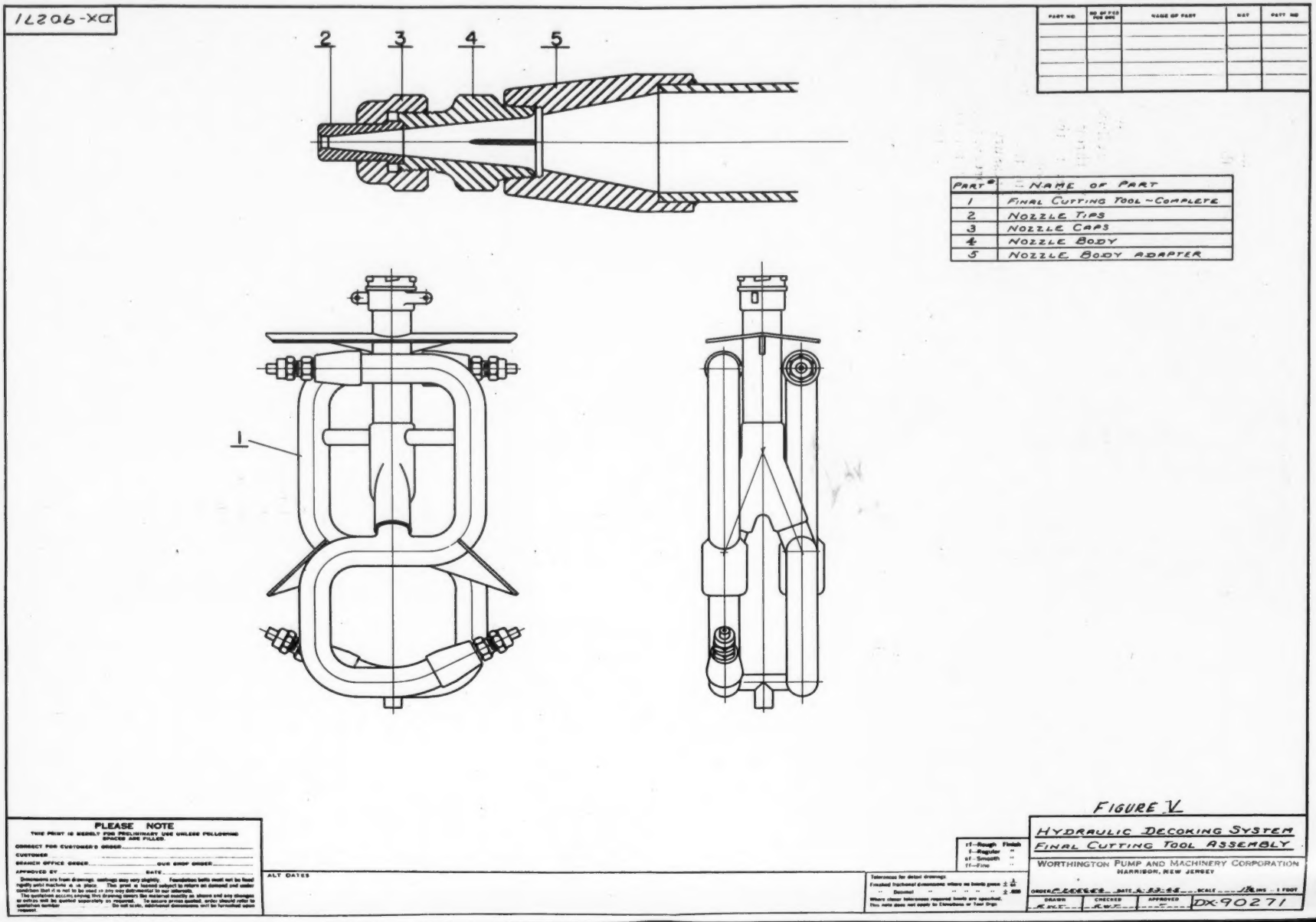
The bubble tower overhead is cooled and condensed in the cooling tower and is separated into gas and gasoline in the reflux accumulator. The gas flows through a back pressure controller to the refinery Central Compressor Station where it is compressed to the Central Absorption Plant pressure. This controller sets the pressure for the entire system so that the pressure on the coke drums and the bubble tower are but 2 lbs.—4 lbs. higher than the 52 lbs. held on the bubble tower reflux accumulator. The resulting pressure at the furnace outlet rides at about 75 lbs.

The stripping and coke drum cooling steam are also condensed in the overhead condensers and removed from the accumulator through a bottom boot. The hydrogen sulphide content is so high that this water must be steam stripped in the refinery Central Deodorizer before it can be delivered to sewer.

Gasoline reflux is pumped back to the top of the bubble tower under control of a temperature element located in the vapor space



Feed exchangers with fractionating columns and coke drums in background.



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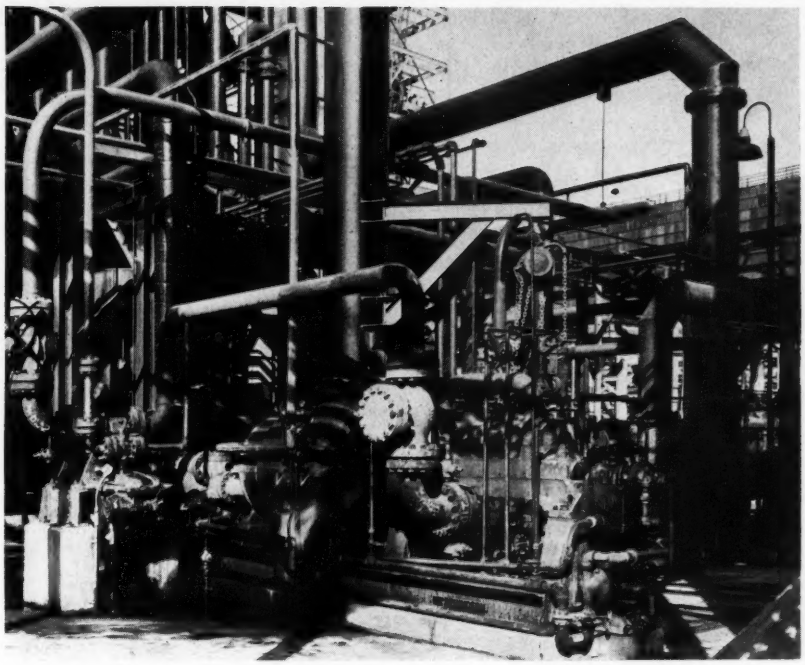
above bubble tray No. 2. The net gasoline make is charged to the debutanizer after heat exchange with the debutanized gasoline. The raw B-B is delivered to raw B-B storage for ultimate Alky Plant feed and the uncondensed vapors to the Central Gas Plant under its own pressure. For more precise control the tower pressure is maintained by a vapor line regulator. In order to insure a steady reflux pressure and thereby smooth out reflux flow, the accumulator pressure too is controlled within narrow limits through the use of a repressuring controller, which bypasses vapors around the condensers to maintain the accumulator pressure, and a depressuring controller which relieves the excess pressure to the gas plant.

Reboil heat is obtained from the intermediate reflux stream. To reduce the tendency to polymerize the cracked gasoline, it was decided to hold the temperature of the heating stream to 600°F or below. Since this stream runs close to 700°F, it is first passed through the first of its four heat exchangers and is satisfactorily cooled by exchange with the fresh feed. A temperature element on the 34th tray controls the quantity of heating oil to the reboiler by positioning a three-way control valve. After passing through the reboiler, or by-passing it, the intermediate reflux stream is further heat exchanged against the fresh feed in the remaining three exchangers and cooled if necessary before it is returned to the bubble tower.

Decoking

Drum Cycle. Operation of the coke drums requires that the furnace transfer line product be switched from one drum to another whenever a drum is filled with coke to the desired outage. At normal feed rates each drum is on stream coking for 24 hours and is off stream for cooling, decoking and heating up for the same period. The drum switches are so timed that one of each pair of drums comes off stream every 12 hours. Under normal conditions the cycle for one drum is about as follows:



Jet water pump and turbine showing at left automatic by-pass valve.

Log of a Typical Drum Cycle

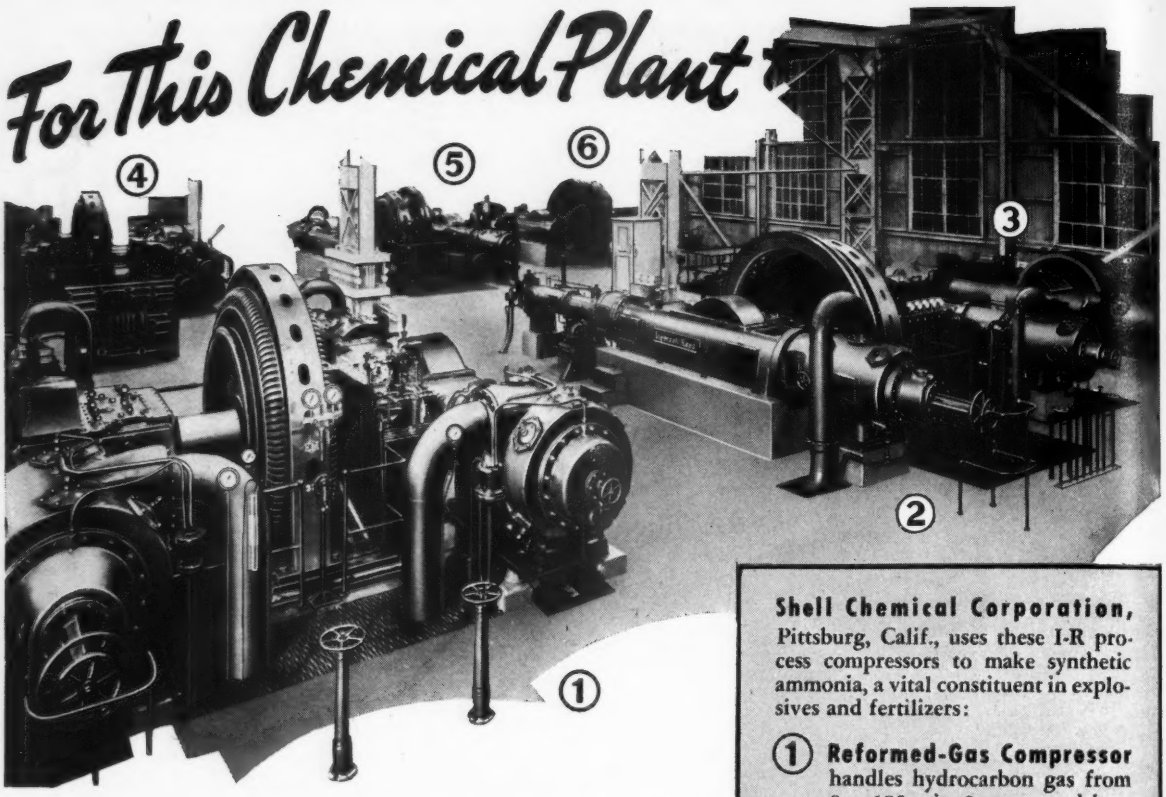
Elapsed Time (Hrs)	Operation
0.0	Switch oil stream to clean drum. Steam full drum to bubble tower.
0.5	Stop steam to bubble tower, steam to blowdown.
0.75	Stop steaming, start cooling with water.
2.75	Stop cooling, start draining water, blinding and unheading.
4.0	Start decoking.
11.0	Finish decoking, start heading up and removing blinds.
12.5	Steam test.
13.0	Finish steam test.
18.0	Start heating.
24.0	Switch in oil stream from full drum.
48.0	Switch oil stream to clean drum.

The transfer line from each furnace is connected to a three-way switch valve which diverts the transfer line product to either coke drum or through a by-pass line to the bubble tower. Before switching the oil from one drum to another, the empty drum is preheated by forcing some vapors from the on-stream drum into the top and pumping the condensate from the bottom of the drum into the bubble tower.

Blowing Down. Whenever the oil stream is switched from a full to an empty drum, the full drum must be purged of volatile oils and cooled down so that decoking operations can be started. After switching out of a drum, steam is immediately cut into it, both into the transfer line to the bottom of the drum and into a steam ring just above the bottom cone. The full drum is steamed to the bubble tower for 30 minutes and is then depressured to the blowdown system. After 15 minutes steaming to the blowdown, the steam is cut out and water is pumped to the steam ring.

This cooling produces considerable steam which must be handled in the blowdown system located about 2,000 feet from the unit area. The blowdown line exhausts into a small tank about six feet below a water level maintained by a continuous circulation through the tank. The circulation is sufficient to remove the superheat of the steam and to condense any oil vapors. Some saturated steam is vented from an 80 ft. stack mounted on top of the tank. The overflow from the tank runs into a skimming sump to re-

For This Chemical Plant



Shell Chemical Corporation, Pittsburg, Calif., uses these I-R process compressors to make synthetic ammonia, a vital constituent in explosives and fertilizers:

1. **Reformed-Gas Compressor** handles hydrocarbon gas from 0 to 185 psig, 2-stage . . . driven by a 1000-hp motor.
2. **Nitrogen Compressor** operates at 0 to 3000 psig, 5-stage . . . 600-hp motor.
3. **Ammonia Compressor . . .** 3 to 141 or 4.7 to 208 psia, 3-stage . . . 200-hp motor.
4. **Air Compressor . . .** 0 to 850 psig, 3-stage . . . 600-hp motor.
5. **Mixed-Gas Compressor** handles nitrogen and hydrogen . . . 145 to 3000 psig, 3-stage . . . 1000-hp motor.
6. **Circulator Compressor** handles hydrogen, nitrogen, ammonia . . . discharging up to 3000 psig, single-stage . . . 900-hp motor.

A maximum over-all plant economy was attained by making many of the frame, running-gear, cylinder, and motor parts interchangeable. Note the 4-corner construction (cylinder on each end of each frame) which provides maximum accessibility.

Each Compressor was built to do a definite job

These six I-R process compressors differ in the gases handled, the pressures generated, the horsepower required, and the operating characteristics. Each was engineered and built to perform its particular job with a high degree of dependability, with a saving in horsepower, and with an ease of operation and control.

Ingersoll-Rand has built the compressors for many synthetic ammonia plants all over the world, as well as for other processes and for handling all kinds of gases. Among these compressors are seven 2500-hp electric-driven seven-stage units compressing nitrogen and hydrogen gas to the super pressure of 15000 psi.

With such *experience* in building and applying compressors for process work, and with a standard line of air and gas compressors from ½ to 3000 horsepower designed for flexibility of application, there is a pretty good chance that Ingersoll-Rand has already built the kind of compressor needed for *your* process. If not, this *know-how* will serve as a background in meeting any new requirements you may have. Remember, Ingersoll-Rand can help solve your compressor problems.

SEVENTY-FIFTH ANNIVERSARY

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TURBO BLOWERS • CONDENSERS
CENTRIFUGAL PUMPS • OIL AND GAS ENGINES

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move any oil. The sump water is cooled by circulation over a 2 bay cooling tower, and a portion of the circulating water is diverted through the blowdown tank to maintain the level. The cooling tower was not designed to handle the instantaneous heat load, but rather the average heat load, the volume of water in the system acting as a flywheel or heat reservoir.

When the coke bed has been cooled to 200-300°F the cooling water is cut out and the drum drained. It is then ready for the decoking crew to start blinding off, opening the heads, and removing the coke.

Operation of the Decoking Equipment. After a drum is cooled and drained the lines leading to the drum are blinded and the manheads removed. With the crusher car positioned under the drum, the boring is begun with the stem rotating at about 8-10 r.p.m. The drill is lowered as fast as possible without allowing the boring tool to actually touch the coke bed. Normally about 15 minutes are required for the high velocity water to cut a hole through the coke. Some water leaks through the bed while drilling, but the majority is held up in the drum until the tool breaks through at the bottom. In the meantime the coke pump is started up and water alone is discharged through the coke line to the storage area until the boring operation is completed.

After the boring is completed, the reaming tool is moved slowly up and down until the hole has been enlarged to about 6 ft. in diameter. This operation requires from 45 minutes to two hours.

After reaming, the cutting tool is installed and the final cutting is begun with the drill stem rotating at about 5-10 r.p.m. The coke is cut from the top of the bed and falls down through the hole into the crusher car. It is usual to lower the tool about 8 in. at a time and rotate it for 2-3 minutes before again lowering. Every 5-10 feet the jet is shut off and the drum is inspected for cleanliness. It has been found necessary to remove the coke completely on the way down since any ledges left behind for later removal will frequently fall into the crusher car and plug up the top grating or will bridge across the bottom of the drum.

Occasionally the coke is cut from the drum at such a rate that the coke pump, operating at medium speed, will not handle it. When this occurs the cutting rate is lowered by reducing the depth of cut until the excess coke is pumped away. The pump can be set to pump at a faster rate, but it is felt that a good average speed has been fixed which does not unduly delay the coking and which does not pump too much water when the cutting rate is lowered as hard coke is encountered. It is also possible to cut coke so fast that resulting large chunks cannot be handled by the crusher. With the proper care in cutting the chunks can be eliminated, but it is easily possible to cut the coke faster than the crusher can handle it. The 18 in. grating added 2 ft. from the top of the crusher car hopper protects the rolls from damage should large chunks inadvertently fall from the drum. It also retains the chunks where they can be manually broken up. When the coke is moderately hard the time required from the beginning of the boring until the drum is completely clean averages about 6½ hours. This corresponds to an overall coke removal rate of about .07 tons per minute. Considering the time consumed in changing tools, inspecting the drum etc., the maximum coke removal rate is probably in excess of one ton per minute.

When the drum is completely clean the transfer line and condensate line are inspected and cleaned if necessary, the steam out valves are blasted with steam and the drum heads are replaced. After removing blinds and steam testing the drum is ready for heating prior to another 24 hours of coking service.

Operations in the Coke Storage Area. The coke-water slurry discharges onto an inclined chute the bottom of which is made of 6-mesh steel screen. The majority of the coke rolls down the screen while the water, together with all material below about 20 mesh, passes through the screen and down a solid chute to a temporary settling pond which is retained by a coke dike. A number of pipes are embedded in the dike and the water overflows through the pipes into a drainage ditch which leads to the secondary settling basin. The coke which rolls off the screen is moved by a bulldozer into piles from which it is loaded onto trucks.

This arrangement for separating the water from the coke is temporary and was devised after our original efforts along the following lines were unsuccessful. Originally it was planned that the coke would be piled in a circular dike of such proportions that the coke and water from one drum cleanout would be retained behind the dike. It was expected that the water would filter off promptly to permit moving the coke out of the way with a bulldozer to make room for the next cleanout. However, the quantity of water (Ca 1,500,000 gals.) and coke from one cleanout was so great that we had difficulty building a dike large enough to contain it. Furthermore, the fines content of the coke plugged the pores of the dike so that 3-4 days were required for the water to filter out.

A permanent coke-water separating installation is under consideration which consists of a screen chute, a series of hoppers which can be used for loading trucks, and a primary settling basin which can be easily cleaned of coke.

Presently, a loading crane is used to move the coke from the pile to the hauling trucks. The load is measured by weighing and delivered to the Great Lakes Carbon Corporation.

To return to the water cycle, two 500,000 gallon secondary settling basins have been provided to permit the deposit removal from one while the other is in settling service. These basins are located at each end of a 3,000,000 gallon storage pond into which they overflow through submerged pipes. The pipes are so located as to leave both the settled and floating fines in the secondary settling basin. The relatively clean water from the storage pond is returned to a surge tank in the unit area by two vertical deep-well pumps. The jet pumps, the drum cooling water pumps, the sluice water, and the automatic make-up water to the coke-slurry

pump suction pit are all supplied from the surge tank.

Make-up water is supplied to the system from the Los Angeles Metropolitan Aqueduct System, or from the refinery wells. Tentative plans have been made to utilize the effluent water from the refinery waste water system for this purpose.

OPERATING CONDITIONS AND YIELDS

Presently the unit is charged with 700 SSF/122 straight run residuum from Wilmington Crude at a rate of 15,000 B/D which effects a recycle to fresh feed ratio of 0.33/1. The 20,000 B/D charged to the furnaces are heated to 920°F.

The bubble tower is operated to produce gasoline with an end-point of 380°F, light gas oil with an end-point of 650°F, and medium gas oil as necessary to maintain a level in the bubble tower bottom reservoir. No heavy gas oil is being removed. In the stripper tower the gas oils are stripped to a flash point which makes them suitable for use as cutter stock, although at the present time the light gas oil is used as TCC charge. Tests are being made to test the feasibility of also using the heavier gas oil in TCC charge.

Under the above operating conditions the following yields were obtained. Additional operating conditions have also been tabulated.

checked by means of the weighed haulings which approximate 500 tons per day.

It is likewise difficult to obtain representative coke samples. Samples obtained show approximately 0.25% ash, 9% volatile matter, and a screen analysis satisfactory for its intended use.

As would be expected with this type of process, the high sulfur Wilmington residuum charge yields a gasoline with an appreciable sulfur content. This sulfur content and the olefinic content of the gasoline are sufficient to require sweetening and rerunning. M. M. clear octane numbers in the neighborhood of 70 are obtained with an octane spread of 8 or better. Lead susceptibility is fair and commensurate with the sulfur content.

Because of the desulfurizing characteristic of the TCC process, the coker gas oils have proven to be quite satisfactory as TCC charge stock despite their high sulfur contents. The 650°F endpoint light coker gas oil, when charged to the TCC units (bead catalyst) with a 1:1 recycle ratio, yielded 41% of 400°F endpoint debutanized gasoline. Furthermore, an octane level of 79 M. M. clear and an octane spread of 10-12 points make this operation look quite attractive.

The low raw B-B yield is a result of the large gas yield from the bubble tower reflux accumulator which carries with it the bulk of the C-4 production. The total gas yield amounts to 8,000-9,000 Mcf/Day. The dry gas after absorption amounts to some 7,000 Mcf/day which is just double the requirements at the Coking Unit furnaces. The excess 3,500 Mcf/Day represents an appreciable contribution to the other refinery units' demands.

OPERATING CONDITIONS AND YIELDS

Operating Conditions	
Reduced Crude Charge	15,000 B/D
Furnace Charge	20,000 B/D
Recycle/Fresh Feed	0.33
Temperatures—Furnace Outlet	920°F
Drum Inlet	900°F
Drum Outlet	830°F
Drum Pressure	56 lbs.
Viscosity of Fresh Feed	700 SSF/122
Yields	
Total Gas	14.0 Wt.%
Raw B-B	0.8 Liq. Vol. %
Debutanized Gasoline	22.5 Liq. Vol. %
Light Gas Oil	36.5 Liq. Vol. %
Medium Gas Oil	16.7 Liq. Vol. %
Coke (By difference)	19.1 Wt. %

It is rather difficult to accurately determine coke yields. Because of varying coke density, measurements by coke drum levels do not appear to be too reliable. The above difference method includes in the coke yield any gains or losses in the process. The yields can be roughly

EFFECT OF OPERATING VARIABLES

Our operating time has been far too short to establish the effects of operating variables. Nevertheless, some indication of their effect has been obtained. Increased viscosity of the charge appears to shift the gasoline and gas oil production slightly toward more gas and coke. Furnace outlet temperature changes through the range 910-920°F also had little effect on gas and gasoline yields; however, gas oil production increased with a decrease in coke yield. Reducing the recycle ratio shifted the yields from coke to the gas oil and lighter products.

From the above indications it appears that any benefit that may be derived from a high removal of straight run gas oil from the charge is not appreciably invalidated by lowered Coke yields; yields may be varied extensively by manipulation of the recycle ratio; and higher furnace outlet temperatures may be feasible.

UNIT FLEXIBILITY

The unit is quite flexible in that it can be used either as a coker, a visbreaker, or any combination of these two. For any operation other than full coking a higher inlet to the coke drum would be used. The rate of residuum withdrawal from the bottom of the drum would determine the amount of coking permitted. In a full visbreaking operation, it is also possible to charge the fresh feed directly to the furnace along with the recycle. Under this arrangement, the residuum would be removed from the bubble tower bottom and the recycle from the bottom draw.

[1]Hulse, S. H., Oil & Gas Journal, June 15, 1946, p-93.

When only a tiny tot, Marguerite Lomax, receptionist for Union Oil Co. in the Los Angeles office was a featured member of the "Our Gang" company, maker for years of a popular series of motion pictures on the typical every day life of youngsters. Her screen name was Marguerite Sinclair.

Practical Aspects of Directional Drilling

ABSTRACT

In this paper the author, after years of practical experience in the drilling of directional wells, discusses the various combinations of drill pipe, drill collars, reamers, bits, weight on bottom, pump pressure and table speed, which can be utilized to reduce the number of primary deflecting tools usually required. The influence of the stratigraphy and structure of the sediments to be penetrated are set forth, together with the methods used to overcome or control these influences. Precautions in the original plans for directional drilling and in the use and operation of equipment are also given. The paper concludes with a summary of the accomplishments in directional drilling and a discussion of the economic phase in its relation to vertical drilling.

* * *

INTRODUCTION

Directional drilling of rotary holes has become common practice in the oil fields, with the recognition by the industry of the savings to be made by exploiting additional reserves in locations too costly or inaccessible for vertical drilling. Although this type of drilling was in limited use in the Signal Hill Field from about 1927 to 1930, the real development of high-angle directional drilling occurred during 1933, with the tapping of the rich oil pool lying beneath the tidelands off Huntington Beach, Orange County, California. Since that time many excellent papers and articles have been written about directed or whipstocked wells, but these have been for the most part confined to descriptions of the primary deflecting tools, the whipstock, knuckle joint and spudding bit, together with methods of running, orienting, and using them in a well bore. This paper is in no way meant to be a repetition of those former articles, but rather to give the practical side of directional drilling with control methods other than with deflecting tools.

To run primary tools such as a whipstock, it is necessary to condition the hole, drill by the whipstock, drill ahead with rathole bit; and, finally, expand the hole to full size if results are as desired. This may involve three or four extra roundtrips. Under some conditions two of these trips can be eliminated by using a differential bit in place of a hole opener. This type of bit, if crowded (i.e., forced by the application of sufficient weight), will follow closely the rathole — thus expanding the hole to full gage and permitting continued drilling without changing the bit.

D. K. Weaver, Wilshire Oil Co., Inc., Norwalk, Calif., and Coast Line Drilling Co., Inglewood, Calif.

A.P.I. November Meeting

Considerable time lost by earlier methods is now saved by the use of the full-gage whipstock, full-gage knuckle joint, and the self-orienting drift master.[1] Bottom orientation by various methods has greatly reduced the time of running primary tools, whereas the non-magnetic drill collar has likewise reduced time of taking directional single shots.

Obviously, the advantage of directional drilling is the ability to direct the well bore along a predetermined course to a desired objective using the minimum number of primary tools. A great deal of knowledge and experience has been gained during the past fifteen years concerning the results of using various combinations of drill-pipe and drill-collar sizes, use of reamers, types of bits, combinations of weight on bit, pump pressure, and rotary-table speed. The following is written in the hope that it will help the industry attain maximum drilling speed and avoid many of the mistakes commonly made by some oil producers when they first undertake directional ventures in their own operations.

Planning the Course

Once a company has decided to drill a directional hole, the first step is to draw a horizontal and vertical plan of the course to be followed. Proper initial planning is essential. The company should keep in mind that the hole must not only be drilled, but must be cased; and later the well must be produced by mechanical means. Usually the position of the finishing depth in the oil zone is plotted as a point with reference to the surface location. In some cases the point of entry to the producing zone is given, as well as the finishing point. This, then, determines the finishing direction and angle of hole. A graphical means of preparing the vertical plan is to increase the angle of the hole at 3 deg per 100 feet, or greater if necessary, until the angle has increased sufficiently to be extended in a straight line and intersect the objective. It is preferable that, when possible, at least the top 150 ft. to 200 ft. of the hole be vertical. Directional work is then planned to start in the first satisfactory geological formation below this depth, usually the first firm or consolidated shale body.

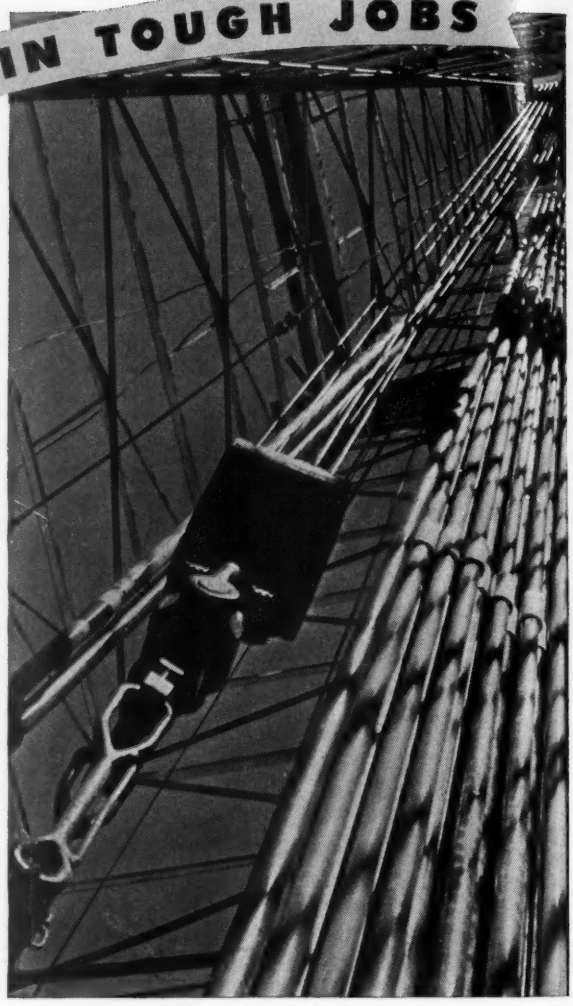
An operator may desire to drill many directional wells with a definite well-spacing program, or he may be required to place wells between other directional holes already drilled. In this instance cylinder drilling, calling for close control, is advantageous. This practice is common in California — and the plan shows a cylinder of predetermined radius with proposed course as the center line. At periodic intervals circles are drawn to represent the cylinder in cross-section. The position of the actual bore can then be plotted at the various levels, showing relation to the center of the cylinder. With this type of drilling, wells have been drilled in a line at Huntington Beach with as little as 30 in. between surface-well centers. With a track, 1 derrick on wheels can service 5 or 6 such wells.

In planning a course it is necessary to fit the directional work into the geological horizon which will permit this type of drilling. Some extremely hard, homogeneous formations would not lend themselves to building angle or a change of direction. However, the course and angle may be maintained if the bore is already on proper course at the

IN THE CALIFORNIA OIL COUNTRY

Purple Strand Wire Rope

SPECIALIZES IN TOUGH JOBS



Take for instance the job handled by a rotary line—probably the toughest assignment you could give a wire rope.

When the hoisting drum starts winding in the rotary line with a mile or so of pipe on the hook, it's a chore that will break the heart of an ordinary rope. But it's made to order for Puple Stand.

Purple Strand is Bethlehem's finest grade of rope. It is made of Improved Plow Steel, the strongest, toughest steel used in commercial wire rope manufacture. It is capable of supporting terrific loads and able to resist the crushing effect of overlap.

There are many other tough jobs in the oil country that call for ropes capable of standing heavy loads, heavy pressures and high speeds. But whatever the job, there is a Bethlehem rope in the size and construction that will fill your bill.

Petroleum Equipment Company carries a complete line of Bethlehem ropes and can supply them on short notice. It isn't necessary for you to tie up a lot of money in rope stocks, simply tell Petroleum Equipment what you want when you want it.

If at any time you would like advice or technical information concerning oil-country ropes Petroleum Equipment will gladly help. They maintain a wire rope specialist whose knowledge of steel-making and rope manufacture may be of value to you in selecting the right rope for the job.

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Subsidiary of Bethlehem Pacific Coast Steel Corporation

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time of encountering such formations.

Some of the early wells directionally drilled were deflected from the surface by tilting the rotary table with a 2-in. to 3-in. block and tying the kelly over to the opposite side. This gave so much trouble in setting the slips when coming in and out of the hole, and later threw such a strain on the surface pumping equipment, that the plan was abandoned in favor of drilling the first few hundred feet vertically.[2] Also, excessive wear occurred at the shoe of the surface pipe which caused many failures. An extra-heavy shoe on the surface pipe is recommended on all occasions.

At Huntington Beach, as the first 700 ft. of formation is unconsolidated sand and gravel, surface pipe is set about 50 ft. into the first shale. Directional work usually is started about 30 ft. below the shoe of the surface pipe. Starting at this depth, the angle is increased from the first whipstock 2½ deg. to 3 deg. per 100 ft., until the angle has reached that determined for the finishing depth in the oil zone. The balance of the course then can be straight, maintaining the same angle to bottom. This results in a smooth curve changing tangentially to a straight line which, experience has proved, is easily drilled, easily cased, and results in a minimum of difficulty after the well is placed on the pump (see Fig. 1; example of horizontal and vertical plan).

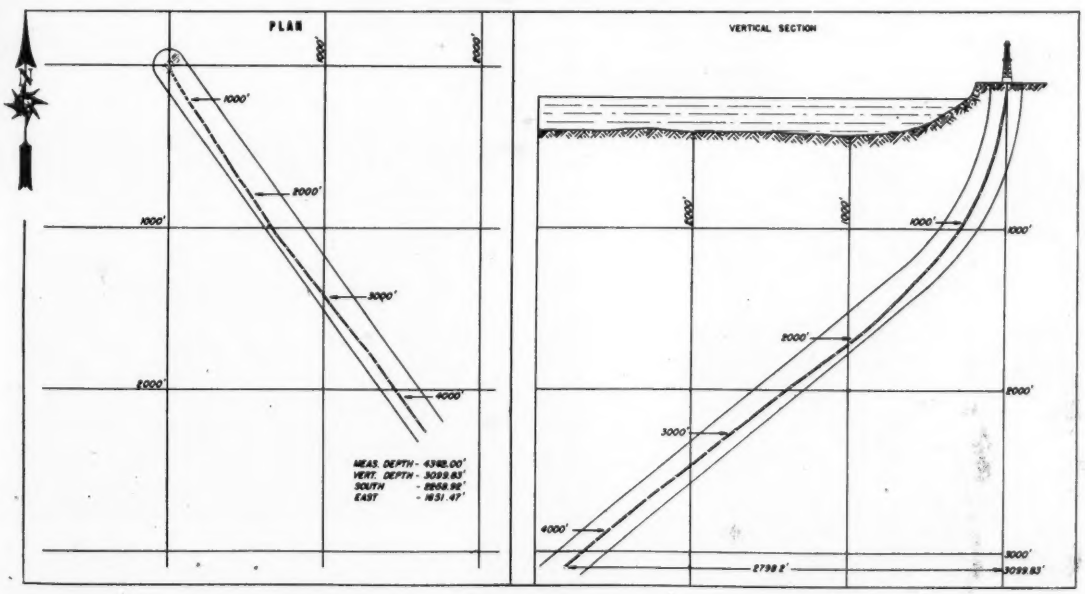
Initial Deflection

Proper choice and setting of the first deflecting tool is important, inasmuch as an incorrect starting direction may require two or more settings to remedy. If the formation is firm, an oriented whipstock is desirable for the initial takeoff. In soft formations a spudding bit works very satisfactorily, either in making the initial deflection from drilled bottom or in drilling off a cement plug. This is a wedged-shaped bit with the back side shaped like the back of a spoon. It is run on a kinked or straight double of drill pipe, and is oriented into the hole and spudded until 2 ft. to 4 ft. of hole have been made—the shape of the bit carrying the hole to the side in the desired direction. Formerly a double of the next smaller size drill pipe with a rathole bit was then run in to make the follow-up hole, which was expanded with hole opener in the usual manner. Spudding bits are now more commonly used as a means of accentuating results from other primary deflecting tools or to aid in sidetracking.

Initial deflection also may be obtained by using the eccentric turbine bit, run on a kinked double of drill pipe or a short length of the preflexed drill pipe used with this bit in drilling drain holes. Probably 5 ft. or 6 ft. of the hole would be sufficient with this combination, which has the advantage that the drill pipe does not rotate once the orientation is made. Bottom-hole orientation, in common use in the Mid-Continent, soon should replace the oriented drill-pipe method.

One of the important considerations in drilling a directional hole is the geology of the local area to be penetrated. A knowledge of the type of sediments and the direction of dip is all-important. In general, directional drilling can be done without excessive cost in most sedimentary rocks where the formations are not too steeply tilted nor too hard.

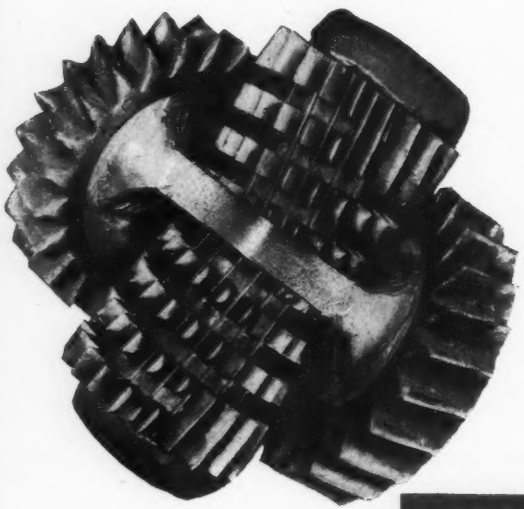
Most bore holes, when given sufficient weight on the bit, tend to climb updip after the angle exceeds 4 deg. Below that angle there is little control of direction, as the hole usually spirals in a clockwise direction—probably influenced by the direction of rotation of the drill. Considerable influence is exerted by alternating hard and soft beds—especially where dips exceed 20 deg to 25 deg—and direction will vary



Horizontal and Vertical Plan for Cylinder Drilling.

H.C. Smith Rock Bits

for Faster, Straighter Full Gauge Holes



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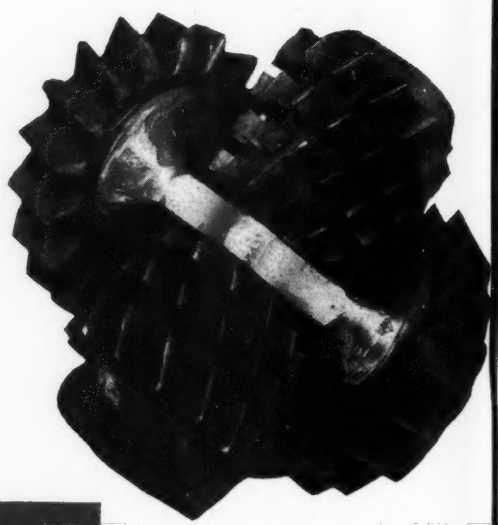
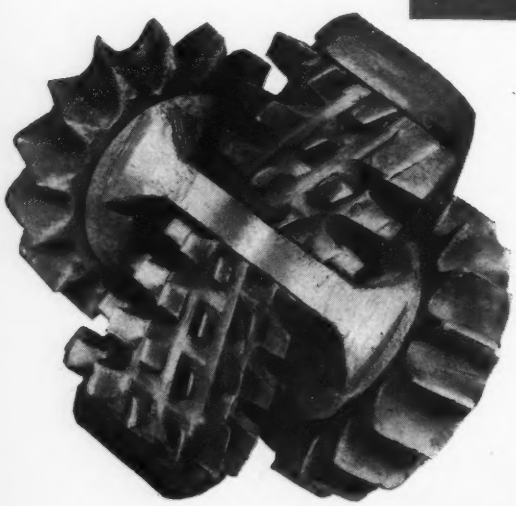


TYPE 2

TYPE K-2



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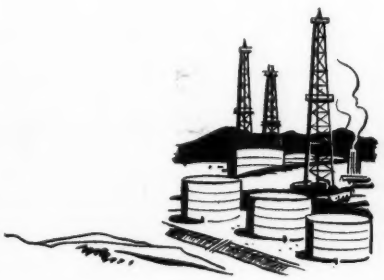
depending on whether the course is updip, along strike, or downdip.

As soon as a bore has reached an angle of 5 deg to 6 deg from vertical, the tendency of the drill is to go in a relatively straight course if going updip, whereas it will usually pull right or clockwise if going downdip. If the course is along the strike, the hole will tend to go downdip. These factors should be considered in making the initial settings with the primary deflecting tools. In other words, if a right pull is expected, a primary setting up to 15 deg to the left of the desired course should be used. If an initial angle of 2½ deg to 3 deg is obtained from the first primary run, this practice allows the drilling ahead with combinations for increasing angle, until the rightpull has taken the hole to the true desired course. To avoid overswing, another primary tool, set from 3 deg to 5 deg left of course, should take the drift angle above 6 deg, where the hole will tend to take off and maintain the desired predetermined course. The 3-to 5-deg. setting should compensate for any remaining right pull. If an overswing occurs, it may take 2 or 3 more primary tool settings to achieve that which would have been accomplished by 1 set at the right time.

To obtain the maximum results from the initial deflecting tool, an open-hole-single-shot picture should first be taken. If the hole is exactly vertical, the setting can be made at once. If there is ½-deg. to 1-deg deflection in the wrong quadrant from the desired start, a little additional drilling with the clockwise-spiralling tendency usually will put the hole in the desired quadrant, where maximum results can be obtained from the initial deflection. This practice naturally requires some leniency from the takeoff point originally planned.

Results of Various Combinations

Once the primary tools have given the initial deflection in the desired direction, the next requirement in directional drilling is to build angle (i.e., to increase the angle). This operation is simple, and the acceleration of angle is usually easily controlled. At this time all necessary tools should be on the rig. In addition to the survey instruments for both open-hole and wire-line single shots, there should be 8-ft. and 12-ft. drill collars made with pin and box, in order to make up combinations for 8 ft., 12 ft., and 20 ft. of drill collars. In addition, there should be one 40-ft. drill collar. Full size reamers with helical cutters—preferably sharp—are used directly above the bit, whereas slightly under-sized reamers for stabilizers with half-flat helical cutters are used above the drill collars, when required. Thus, if the bottom reamer is 10⅝ in., a 9⅝-in. stabilizing



reamer is used above; and, if a 12¼-in. bottom reamer is used, a 10⅝-in. stabilizer is used. A complete selection of bits should be available, including drag-and rock-type heads.

The first requisite for building angle is a reamer, placed just above the bit, or with a short sub between. With ample weight on bottom the reamer then becomes a fulcrum, prying the bit gradually upward. The reamer should have helical-type cutters, as these are the only design that will turn and not run a flat in a slant hole.

It is possible to build angle at a greatly varied rate by using drill collars of different lengths or no drill collar at all. The rate of change in the angle of 4 deg. per 100 ft. is about the maximum desired for the average directional hole, and for this rate an 8- to 12-ft. drill collar is usually satisfactory. Sufficient weight must be carried to keep the reamer prying the bit upward. At the same time the table speed should be slow, and only sufficient pump pressure used to insure adequate cleaning of the bit and reamer. Too much circulation in soft formations will wash a cavity which may cause the hole to drop angle (i.e., to decrease the angle).

A generalized tabulation is shown hereinafter for angle control, which may be a guide to the operator.

70 Revolutions Per Minute—6 Tons Weight—4½-In. Drill Pipe—10⅝-In. to 11½-In. Hole

Increase Per 100 Ft (Deg)	Drill Collar, if Any with Reamer Below (Ft)
0-½	80-120
½-1	40
1-2	30
2-3	20
3-5	8-12
5-7	No drill collar
7 plus	No drill collar and 3½-in. double

Another method for angle building is to use the usual bit and reamers on bottom, then a 12- to 15-ft. joint of drill pipe above the reamer, and 80 ft. of drill collars above the short joint of drill pipe. This assembly can be rotated up to 150 rpm with only about 2 tons of weight and will build angle as rapidly as 4 deg to 5 deg per 100 ft.

It must be kept in mind, where tons of weight on the bit are mentioned, that this is in the initial angle-building procedure. As the angle in the hole increases, wall friction absorbs more and more of the weight shown on the weight indicator. In drilling a hole with angle up to 50 deg or 60 deg, the indicator weight carried on bottom may be as high as 12 to 15 tons in order to have 7 to 8 effective tons on the bit itself.

It can be seen that a wide variation in increase of deflection is possible merely by lengthening or shortening the drill collar, increasing or decreasing the weight on bottom, and increasing or decreasing the table speed. Whatever combination is used, it must be remembered that sufficient weight on the bit and slow table speed are necessary. High speed of rotation and 2 to 3 tons of weight will cause a hole to drop angle immediately.

Hardness of the formations, as well as the direction of dip, causes quite a variation in these combinations. If, for example, with an 8-ft. drill collar, reamer below, 7 tons of weight, and 70 rpm, the angle is

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versus

Mechanically operated instruments

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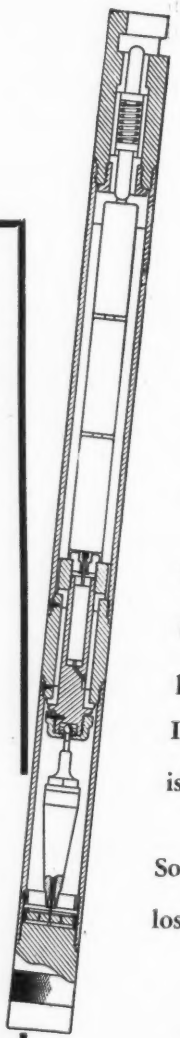
2. On Sand Line.
3. As a Go-Devil and recovered when changing bit.
4. As a Go-Devil and picked up with a core-barrel overshot.
5. Run in with a core-barrel overshot when picking up a core.
6. Run inside of bailer in cable tool drilling.



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ccelerating 4 deg per 100 feet and 3 deg per 100 ft. is desired, reduction of 1 to 2 tons weight on the bit with increased table speed of approximately 20 rpm may produce the correct results. A drill collar, 20 ft. in length, would accomplish this with the original weight and speed, but would require a round-trip. The exact combination must be experimental, taking a sufficient number of angle shots at close intervals to insure the desired results. Once the desired angle has been attained, a 40-ft. drill collar can be used with the full-sized reamer below, and a slightly smaller stabilizing reamer above the drill collar. Another variation—probably more desirable because of difficulty in keeping the stabilizing reamer clean—is to use 80 ft. of drill collars with the bottom reamer only. The greatest hazard in running too long and too stiff a combination of drill collars is the possibility of sidetracking the hole in the portion where maximum angle building occurred. If this part has been thoroughly reamed, sidetracking can be avoided by crowding the bit through without rotating until the straight-line part of the course has been reached.

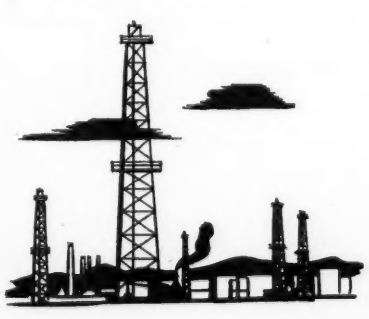
If, for any reason, it is desired to drop angle rapidly, the full-sized reamer is carried on top of a 30- to 40-ft. drill collar, with only the bit below. Application of the same amount of weight as carried in accelerating angle will cause a drop of from 5 deg to 6 deg per 100 ft. The fulcrum in this instance is the reamer above the drill collar, which pries the bit downward. The same condition will exist if the angle is allowed to drop from excessive table speed and too little weight. The fulcrum is then at the point of reverse bend, and the hole will lose angle rapidly with the application of weight. In many instances primary tools are necessary to overcome a dive or reverse bend which has been allowed to develop.

It should be emphasized that during angle building or changing of direction, sufficient number of single-shot pictures should be taken to avoid losing control of the hole. If a reverse bend or overswing is never allowed to develop, no serious loss of time nor extra expense can occur. A picture every 20 ft. to 30 ft. will often enable the operator to make sufficient changes in operating procedure, if control loss is indicated. If the combination is in use for building angle, and angle shots inside of drill pipe indicate that the angle is not appreciably changing, a directional shot should be taken at once, because a right or left swing is probably developing. Something must happen with the use of all combinations chosen to build angle. If it is not a change up or down, it must be to the right or left. Sufficient single shots taken at close intervals will enable the operator to keep or regain directional control.

Trained, intelligent drilling crews can greatly facilitate directional drilling. Drillers should be shown the proposed course and actual drilling progress so they may have a clear idea of what is to be accomplished. Experienced drillers know that the slow table speed and excessive weight on bottom are essential for results. They are thoroughly familiar with combinations of bits, reamers, and drill collars, and what can be accomplished by their use. At least the drillers and derrickmen should be able to run directional single shots and correctly read the results. The telephone then can save much lost sleep and travel time for the tool pusher and petroleum engineer.

Bits for Directional Drilling

The performance of various types of bits in the hole is one of the most controversial parts of this subject. It has been claimed that some bits pull to the left, others to the right; and, in some cases, the claims appear to be true. However, it is extremely doubtful if any type of bit will consistently, and under all conditions, pull one direction or the other. It is thought that the direction in which the bit is encountering the dipping formations and the nature of the stratigraphy play by far the more important part.



Many of the early directional holes were drilled with a 3-way disc bit. Its drawback was the inability to survey through it as is done with wire-line coring bits. However, the development of non-magnetic drill collars, now available, would eliminate this objection. Slant-hole drilling is done with either 3 or 4 bladed drag bits or rock bits, which may be cross-section or cone-type. Directional work is easier when drilling with drag bits, but this is probably because the softer formations which permit drag-bit drilling facilitate drift. Although the wire-line-type bits permit open-hole single shots without coming out of the hole, these bits do not make the amount of footage possible with the conventional type. For this reason the non-magnetic drill collar has a decided advantage in allowing more footage per bit as well as permitting directional single shots without retrieving a center bit. These collars are 23 ft. long with steel subs for the top and bottom. They rent for $50 per day, but on outright purchase at about $3,500 would be justified if a continuous program of directional work was planned. Single shots in these drill collars usually show about ½ deg less angle than open-hole shots, whereas pictures taken through a center bit hole may be from ¾ deg to 1 deg less angle than is shown from an open-hole picture.

Recently there have been developed special directional drilling bits called "trigger bits," through which a survey barrel can be run and allowed to protrude below the bit sufficiently to permit a directional picture.

Variations also occur in the results obtained from using the differential bit as a hole opener. In the Rincon Field this bit followed the rathole by the whipstock perfectly, whereas in the Jacalitos Canyon Field the same bit consistently sidetracked the rathole and was dis-

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continued in favor of the conventional hole opener. Full-size primary tools will eliminate side-tracking of the rathole.

It is felt that the most satisfactory method of altering the course of a hole to right or left is to use either a whipstock or knuckle joint. The latter has done some excellent work with far less mechanical hazard in a high angle hole. For maximum turn with a knuckle joint, the hole can be underreamed locally, as the amount of turn depends on the size of the hole in which the knuckle joint is used.

Precautions

In planning the hole size for a directional well, a little additional clearance should be allowed. If the hole is thoroughly reamed, 8⅝-in. collared casing will follow a 12¼-in. hole, accelerated as much as 5 deg per 100 ft. to a drilled depth of at least 3,500 to 4,000 ft. Similarly, a 7-in. collared casing will follow a 10⅝-in. hole; 5 9/16-in. drill pipe is commonly used in hole sizes from 12¼ in. to 15 in. in diameter, but does not allow angle building much in excess of 3 deg to 4 deg per 100 ft. The most common size of drill pipe for directional work is 4½ in., which lends itself readily to all combinations of hole sizes from 9 in. to 12¼ in. Extreme caution must be used in drilling directionally with 3½-in. drill pipe, inasmuch as it is possible to flex this or a smaller size beyond the angle that can be followed by casing. Less weight carried on bottom, a little higher speed of rotation, and sufficient number of angle shots will avoid loss of control when using 3½ in. drill pipe.

In developing a right or left turn in a well bore, care must be taken to avoid an overswing. If the use of a 40-ft. or longer drill collar does not overcome this tendency, a rathole drilled for 20 ft. or 30 ft. followed by a hole opener may be successful. Care must be taken in this operation not to crowd the bit, but to let it start to dig with minimum weight and relatively high speed of rotation. If the swing comes around to the exact desired course and more angle is needed, a whipstock set for angle only and

no change in direction will stop this swing.

In high-angle drilling, there are always excessive risks of a fishing job, the chief causes being key seating, improper handling of mud, insufficient reaming, and carelessness. The bore must be properly mudded to avoid any sloughing, and the sand content of the mud kept at an absolute minimum. Key seating can result from too rapid angle building, as well as insufficient drilling progress where the drill pipe rotates with very little change in position. One exceptionally bad fishing job resulted when, with a high sand content in the mud, the driller pulled the bit only 5 ft. off bottom and, without rotating the pipe, allowed the crew to grease up. Another resulted from making a minor clutch repair on the rotary after pulling just 11 ft. off bottom. Each of these very costly jobs (necessitating redrill of most of the hole in one case, and a long wash-over job in the other) could have been avoided by a little care and foresight. It is recommended always to come out of the hole for any repairs. When greasing up, the bit should be pulled well off the bottom and kept rotating, except when greasing the rotary drive itself. Mud circulation should be maintained.

Although considerable torque builds up during the drilling of high-angle holes, it is rarely sufficient to cause failure in modern drill pipe without other contributing causes. One company reported a 30-per-cent reduction in torque in a 60-deg-angle hole when using 4½-in. instead of 5 9/16-in. drill pipe. It was also reported that the amount of torque developed in 1 hole with a 60-deg angle from 1,800-ft. to 5,500-ft. drilled depth indicated that grade "E" drill pipe should be used for deeper drilling.

In the drilling of wells with extremely high angle, it is recommended that a protection string of casing be set after all angle has been built, and the course straightened out in line with the final objective. In this manner most fishing jobs will be avoided. However, if they do occur, the expensive portion of the hole is saved.

It is extremely hazardous to run flush-joint casing in a slant hole. The collars are essential to break up the mud sheath on the wall, and a long string of flush-joint casing acts the same as a flat pane of glass dropped in the mud. Surface tension may freeze the casing. Long flush-joint liners have been run successfully at Huntington Beach, where drilling into the oil zone was done with oil as the circulating medium.

There is particular difficulty in forcing cement completely around the casing in a slant hole, inasmuch as the pipe lies on the low side and the circulation flows more readily along the high side of the casing. In cementing, several spring equalizers are desirable—usually 3 or 4 on the shoe joint, with 2 or 3 on each of the next 2 joints above. The use of several wire scratchers on the bottom 2 joints is recommended, even though they became mashed down while the casing is being run.

If the oil zone has been penetrated prior to running the water string, it is desirable to test for water shut-off by shooting holes 5 ft. to 10 ft. above the shoe. A running cement bridge placed below the shoe has in some instances caused the sidetracking of the hole below.

In 2 instances at Huntington Beach holes which had already reached the cementing point were lost at shallow depths and later recovered. History of the remedial measures may be of benefit to others having a similar experience. One well had reached a drilled depth of 4,340 ft., and was ready to be cased

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following electric logging. At a depth of 600 ft. in very soft formation, a whipstock run had caused an increase of drift angle of 6 deg in 40 ft. Constant reaming apparently had smoothed out this dog leg, but the electric-logging instrument would not go below this point, and spudding it started a definite shoulder. At this time a pilot bit might have guided the pipe into the hole and smoothed off the shoulder. However, an ordinary drag bit was run back into the hole and worked down for 20 ft. without dropping free. By slow rotation, another 80 ft. was drilled with the bit taking all the weight when rotation ceased. An open-hole single shot showed a 22-deg angle, at a depth where previously a 29½-deg angle had been recorded; 22 deg was the angle of the hole prior to setting the whipstock at 1,600 ft., so the bit had taken off below the old hole in a straight line. The new hole was plugged solid with cement, and the top of the plug smoothed off at 1,600 ft. A whipstock was set the same as the original one. After rotating and drilling ahead 2 ft., the bit dropped into the old hole. Within 48 hours the hole was saved and safely cased to bottom. The same practice was used in the second instance with equal success. It is believed that lost hole can be recovered in almost every instance if the exact point of takeoff is known, and good survey records have been kept on the original hole. Such loss invariably will occur at a bad dog leg, with the new hole taking off along its previous course. It is necessary, therefore, to plug the new hole solid with cement to avoid the future danger of entering the new hole while running casing. By coming to the exact point of loss, the operator is dealing with 2 dimensions. At any other point 3 dimensions are involved, and an error of 1 ft. may result in missing the hole altogether. If the second whipstock setting is the same as the first, the bit must go into the old hole. However, before a new hole should be allowed to develop, a pilot bit, preferably a "side-hill" type, should be tried first.

Accomplishments

Operators in different producing areas in the United States have varying concepts of high-angle holes. The average slant hole in the Rocky Mountain states is about 6 deg. In the Gulf Coastal fields the average angle of deflection is 14 deg to 15 deg; whereas on the Pacific Coast 30 deg is the average, and 60-deg angle holes are relatively common.

Some rather remarkable results have been recorded which show the possibilities of slant-hole drilling. One well in the Argentine had an acceleration of 5-deg per 100 ft. from the surface, attaining an angle of 45 deg at 900 ft. A well drilled under tidelands in the Rincon Field was drilled vertically for 165 ft., and reached an angle of 56 deg from vertical at a drilled depth of 1,230 ft. Total horizontal drift of this well was approximaetly 3,150 ft. in attaining a vertical depth slightly less than 2,800 ft.[2] Another record hole was drilled at Seal Beach to about 7,000 ft. where an angle in excess of 80 deg from vertical was developed with a horizontal drift of approximately 5,500 ft.

Several tideland wells at Huntington Beach have exceeded 60 deg from vertical at drilled depths ranging from 4,000 ft. to 4,500 ft. Horizontal drift was approximately 3,000 ft, and close control was maintained. One such well was confined to a 50-ft. radius cylinder from the surface to bottom, yet was drilled to within 20 ft. of its objective with only 5 primary tools.

About 6 years ago in the Long Beach Harbor area, directional wells drilled to depths of 3,200 ft. to 3,300 ft. took from 24 to 28 drilling days. Today, with trained crews and improved tools and methods, similar holes require from 9 to 14 days to complete.

Slant-hole drilling might be carried much further by the development of a ramp or sloping platform, adjustable to a desired angle, in place of the usual derrick or mast. Thus, the hole actually could be aimed toward the objective from the surface. Drilling could be done by a hydraulically driven rotary table, with the pipe snubbed in and out of the hole. This same hydraulic drive could snub the casing into the hole, greatly reducing the hazard of sticking the pipe. These wells could be pumped hydraulically, with bailing as the chief mechanical problem.

Whereas it is difficult to lay down hard-and-fast rules reduced to dollars and cents, there are some conditions under which directional drilling should not be attempted.

At present it is inadvisable to drill directionally at depths in excess of 9,000 ft. It is possible, but costly and hazardous. It is equally undesirable to whipstock wells in steeply dipping, alternating hard and soft formations, or in hard formations which cannot be drilled at a rate in excess of 2 ft. per hour. In rugged topography with fairly easy drilling in sands and shales—such as the 4,500-ft. wells in the Jacalitos Field—a directional well will cost about $4,500 to $5,000 more than a vertical hole. If, then, a vertical location is possible by an expenditure of an amount under $5,000, the vertical well is always recommended.

In tideland drilling the cost of constructing, maintaining, and later abandoning piers is staggering. If a 60-deg slant hole can reach the objective, pier drilling should not be considered unless onshore locations are unavailable.

The choice between vertical and directional drilling must be a matter of economics. In many instances a few thousand dollars additional money spent for a vertical location is well justified. However, directional drilling does have a place where vertical locations are almost inaccessible, or are prevented by legislation.

ACKNOWLEDGMENT

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Tentative Partial Enthalpies of the Lighter Hydrocarbons

B. H. Sage, R. H. Olds, and W. N. Lacey
California Institute of Technology

October Meeting

Estimation of the heat and work associated with changes in the state of materials of industrial interest is frequently required in engineering practice. This is particularly true in the petroleum industry where changes in phase are often involved in essential processes. In the present paper the thermodynamic approach to the evaluation of the heat associated with the transfer of material from a gas to a liquid phase for the case of pure hydrocarbons and for that of multicomponent mixtures is discussed. The utility of the partial thermodynamic properties of the components in the estimation of the heat and work for such changes in state for mixtures is indicated. Values of the partial enthalpies of the components of binary hydrocarbon systems are presented for some cases in which the experimental data necessary for the calculations are available.

The heat of vaporization of pure substances has been the subject of many investigations and there is available a large background of experimental facts from which a number of generalizations have been made.[1] This work has been reviewed and the results correlated elsewhere[1,2] and so it will not be treated here.

The experimental techniques for the measurement of the enthalpy change during vaporization of a pure substance which were developed to a state of great refinement by Osborne and co-workers[3] are applicable to a wide variety of substances and permit the determination of this quantity with small uncertainty. In addition sufficiently accurate methods of determining the volumetric behavior of pure substances[4,5,6] have been developed so as to permit satisfactory use of the Clapeyron equation[7] for the evaluation of the enthalpy change during vaporization of a pure substance. Less elaborate calorimetric techniques than those of Osborne and co-workers were used by Dana et al[8] and by others[9] to determine this same quantity for each of a number of the lighter paraffin hydrocarbons.

In the case of mixtures, the contribution of each component to the enthalpy of a phase may be evaluated from the partial enthalpy[10] of the pure substances making up the mixture. The partial enthalpy of a component in a mixture may be regarded as the effective contribution of a unit weight of that component to the enthalpy of the mixture. The enthalpy contribution of each component is measured under conditions of constant pressure, temperature, and at a given composition of the system, and its value is a function of the state of the system.

The change in partial enthalpy associated with the solution of a component, which is often loosely called the heat of solution, is a quantity which is somewhat analogous to the enthalpy change occurring as a result of the vaporization of a pure substance. However, the change in state does not necessarily take place under isothermal-isobaric conditions and there results a change in composition in one or both of the phases involved. Few direct measurements of the enthalpy change during the solution of hydrocarbons have been made. This is probably because of the experimental difficulty of such measurements and certain complexities in the interpretation of the data for situations involving more than a single volatile component. Scheibel and Jenny[11] proposed a nomographic chart as a means of recording the enthalpy changes for solution of a number of the lighter hydrocarbons in other hydrocarbons. Data based upon calorimetric measurements for the partial enthalpy change when ethane and propane dissolve in a

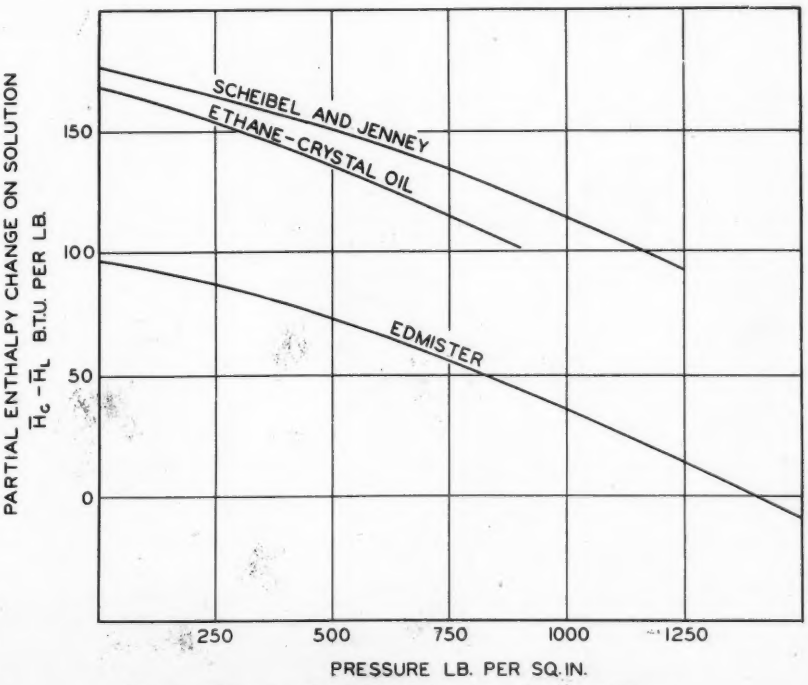

Fig. 1. Change in Partial Enthalpy for Solution of Ethane.

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46-K

TABLE I
PARTIAL ENTHALPIES OF METHANE IN THE GAS PHASE

Weight Fraction Methane	Pressure lb./sq. in. Absolute	70° F.	100° F.	130° F.	160° F.	190° F.	220° F.	250° F.
				Pure Methane				
1.0	0	5.3*	21.3	37.7	54.4	71.4	88.9	106.7
	100	2.9	18.7	35.3	52.2	69.5	87.2	105.2
	200	0.2	16.2	33.0	50.1	67.6	85.4	103.6
	400	− 5.9	11.1	28.3	45.8	63.7	81.8	100.2
	600	− 13.0	5.6	23.5	41.5	59.8	78.2	97.0
	800	− 21.0	0.2	18.8	37.1	55.8	74.6	93.8
	1000	− 28.8	− 5.1	14.1	33.1	52.0	71.2	90.7
	1250	− 36.4	− 11.8	8.3	27.9	47.4	67.0	86.9
	1500	− 43.7	− 18.2	2.7	23.0	42.9	63.0	83.2
	2000	− 57.2	− 30.2	− 7.5	13.7	34.5	55.3	76.3
	2500	− 68.6	− 40.5	− 16.6	5.4	26.8	48.4	69.9
	3000	− 77.5	− 48.8	− 24.4	1.8	20.0	42.1	64.3
				Methane-Ethane System				
0.20	0	.....	21.3	37.7	54.4	71.4	88.9	106.7
	100	.....	19.9	36.4	53.2	70.3	87.9	105.9
	200	.....	19.2	35.6	52.3	69.4	87.1	105.1
	400	.....	20.5	35.5	51.5	68.3	85.9	104.1
	600	.....	26.0	38.0	52.6	68.5	85.7	103.6
	800	.....	35.8	42.9	55.5	69.9	86.1	103.8
	1000	.....	50.5	50.9	60.2	72.7	87.7	104.4
	1250	.....	74.9	65.3	68.9	77.9	90.6	105.7
	1500	.....	101.8	83.3	79.4	83.0	93.3	106.9
	1750	.....	98.0	81.9	79.4	83.2	94.2	107.1
	2000	.....	84.6	71.7	72.0	78.3	91.4	105.2
	2500	.....	61.3	51.4	54.6	63.8	79.1	94.5
	3000	.....	43.3	34.4	38.8	49.1	65.1	81.5
0.40	0	5.3	21.3	37.7	54.4	71.4	88.9	106.7
	100	3.2	19.4	35.8	52.6	69.9	87.5	105.3
	200	1.2	17.5	34.0	51.0	68.4	86.1	104.0
	400	− 2.2	14.2	30.9	47.9	65.6	83.5	101.6
	600	− 4.3	11.7	28.4	45.3	63.0	81.0	99.3
	800	− 5.0	10.4	26.4	43.1	60.7	78.7	97.2
	1000	− 3.9	10.2	25.3	41.3	58.7	76.6	95.1
	1250	− 0.8	11.7	24.9	39.5	56.5	74.3	92.7
	1500	− 6.3	12.6	24.4	37.8	54.4	72.0	90.2
	1750	− 20.3	7.7	22.3	35.8	52.1	69.7	87.7
	2000	− 34.1	0.1	18.1	33.1	49.7	67.1	84.9
	2500	− 57.3	− 16.8	6.3	25.0	43.3	61.1	78.2
	3000	− 74.3	− 31.0	− 5.5	15.3	35.1	53.5	70.6
0.60	0	5.3	21.3	37.7	54.4	71.4	88.9	106.7
	100	2.5	18.8	35.5	52.5	69.7	87.3	105.2
	200	− 0.2	16.5	33.4	50.5	68.0	85.8	103.8
	400	− 5.3	11.8	29.2	46.7	64.6	82.8	101.0
	600	− 10.1	7.3	25.1	42.9	61.1	79.7	98.3
	800	− 14.9	2.9	21.0	39.2	57.7	76.7	95.6
	1000	− 19.9	− 1.6	16.9	35.6	54.5	73.9	92.9
	1250	− 26.6	− 7.5	11.7	31.0	50.5	70.3	89.7
	1500	− 34.3	− 13.8	6.4	26.6	46.6	66.8	86.4
	1750	− 42.8	− 20.7	1.1	22.3	42.8	63.4	83.2
	2000	− 51.5	− 27.7	− 4.3	18.1	39.1	60.0	80.1
	2500	− 67.6	− 40.7	− 14.3	9.9	31.9	53.4	73.8
	3000	− 80.4	− 51.2	− 23.1	2.3	25.1	47.1	67.8
0.80	0	5.3	21.3	37.7	54.4	71.4	88.9	106.7
	100	2.4	18.8	35.5	52.4	69.4	87.1	105.1
	200	− 0.3	16.3	33.2	50.3	67.4	85.4	103.6
	400	− 6.0	11.2	28.6	46.0	63.6	82.0	100.5
	600	− 11.7	6.0	24.0	41.7	59.9	79.6	97.4
	800	− 17.7	0.8	19.3	37.6	56.1	75.2	49.3
	1000	− 23.6	− 4.4	14.6	33.5	52.4	71.8	91.3
	1250	− 31.1	− 10.9	8.8	28.3	47.8	67.6	87.4
	1500	− 38.4	− 17.4	3.2	23.3	43.3	63.6	83.7
	1750	− 45.6	− 23.7	− 2.4	18.5	39.0	59.6	80.1
	2000	− 52.5	− 29.7	− 7.7	13.8	34.8	55.9	76.6
	2500	− 65.0	− 40.7	− 17.3	5.2	27.2	48.9	70.0
	3000	− 75.3	− 49.9	− 25.5	− 2.2	20.5	42.7	64.2
				Methane-Propane System				
0.40	0	5.3	21.3	37.7	54.4	71.4	88.9	106.7
	200	3.1	19.2	35.7	52.2	69.2	86.4	104.3
	400	3.0	18.8	35.1	51.4	67.9	84.5	102.2
	600	.....	.....	35.4	51.5	67.5	83.3	100.5
	800	.....	.....	.....	52.2	68.1	82.9	99.4
	1000	.....	.....	.....	53.6	69.1	83.2	98.9
	1250	.....	.....	.....	.....	70.1	83.9	99.2
	1500	.....	.....	.....	.....	69.0	84.8	100.7
0.60	0	5.3	21.3	37.7	54.4	71.4	88.9	106.7
	200	0.2	16.7	33.6	50.6	67.8	85.6	103.7
	400	− 5.2	11.9	29.3	46.6	64.1	82.2	100.6
	600	− 10.8	6.8	24.8	42.5	60.3	78.7	97.6
	800	.....	1.4	20.0	38.1	56.5	75.3	94.6
	1000	.....	− 4.8	14.6	33.6	52.7	72.0	91.7
	1250	.....	.....	7.1	27.5	47.8	68.0	88.2
	1500	.....	.....	.....	21.0	42.9	64.3	84.9
0.80	0	5.3	21.3	37.7	54.4	71.4	88.9	106.7
	200	− 0.2	16.4	33.3	50.3	67.7	85.4	103.5
	400	− 6.0	11.2	28.6	46.1	63.8	81.9	100.3
	600	− 12.0	5.9	23.8	41.7	59.9	78.2	97.0
	800	− 18.2	0.4	19.0	37.4	55.9	74.6	93.7
	1000	− 24.6	− 5.2	14.1	32.9	52.0	71.1	90.5
	1250	− 32.7	− 12.5	7.8	27.3	47.3	66.8	86.6
	1500	− 41.1	− 20.2	1.3	21.7	42.8	62.6	82.9

non-volatile oil are available.[12] Values for ethane from this source agree within the calorimetric uncertainties with those read from the nomograph. Edmister[13] proposed a means of predicting the enthalpy change for solution of a hydrocarbon from information concerning its thermodynamic characteristics in a pure state. Values for the enthalpy change for solution of ethane have been computed on this basis for 160°F and are shown in Figure 1. The divergences of these values from those obtained calorimetrically[12] and from the Scheibel and Jenny nomograph[11] indicate a relatively large uncertainty in the prediction of the enthalpy change for solution of the lighter hydrocarbons.

When the complexity of industrial hydrocarbon mixtures and the variability of prevailing conditions are considered, it seems unlikely that any very simple means of predicting their properties will be capable of high accuracy. It therefore becomes

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TABLE I
PARTIAL ENTHALPIES OF METHANE IN THE GAS PHASE (Continued)

Weight Fraction Methane	Pressure lb./sq. in. Absolute	70° F.	100° F.	130° F.	160° F.	190° F.	220° F.	250° F.
				Methane-n-Butane System				
0.60	0	5.3	21.3	37.7	54.4	71.4	88.9	106.7
	100	.....	19.9	36.7	53.9	71.3	88.8	106.6
	200	.....	18.3	35.7	53.4	71.0	88.6	106.3
	400	.....	16.3	33.3	52.0	70.1	87.9	105.5
	600	.....	14.1	30.2	50.0	68.6	86.6	104.2
	800	.....	.....	26.3	47.4	66.6	84.9	102.7
	1000	.....	.....	21.7	44.1	64.2	82.9	100.8
	1250	.....	.....	15.4	39.4	60.6	79.9	98.2
	1500	.....	.....	8.6	34.2	56.5	76.6	95.3
	1750	.....	.....	1.7	28.7	52.0	73.0	92.3
	2000	.....	.....	− 5.2	23.1	47.4	69.2	89.1
	2500	.....	.....	− 18.6	11.7	38.0	61.4	82.8
	3000	.....	.....	− 31.1	1.1	29.2	54.2	77.0
0.80	0	5.3	21.3	37.7	54.4	71.4	88.9	106.7
	100	2.9	19.1	35.7	52.5	69.7	87.3	105.3
	200	0.4	16.8	33.6	50.6	67.9	85.7	103.8
	400	− 4.9	12.0	29.1	46.6	64.3	82.4	100.9
	600	− 10.2	7.0	24.5	42.4	60.4	78.9	97.8
	800	− 15.7	1.9	19.7	38.1	56.5	75.4	94.7
	1000	− 21.3	− 3.2	14.9	33.8	52.6	71.8	91.6
	1250	− 28.1	− 9.6	9.0	28.4	47.8	67.5	87.7
	1500	− 34.6	− 15.7	3.3	23.1	43.0	63.2	83.9
	1750	− 40.7	− 21.4	− 2.1	18.1	38.4	59.2	80.2
	2000	− 46.2	− 26.8	− 7.2	13.3	34.0	55.2	76.6
	2500	− 56.4	− 36.5	− 16.4	4.7	26.1	47.8	70.0
	3000	− 65.6	− 45.2	− 24.4	− 2.8	19.1	41.4	64.1
0.90	0	5.3	21.3	37.7	54.4	71.4	88.9	106.7
	100	2.7	18.9	35.5	52.4	69.6	87.2	105.2
	200	− 0.1	16.4	33.2	50.4	67.8	85.6	103.7
	400	− 5.8	11.2	28.5	46.1	64.0	82.2	100.7
	600	− 11.7	6.0	23.6	41.7	60.1	78.7	97.6
	800	− 17.6	0.6	18.6	37.3	56.1	75.2	94.5
	1000	− 23.5	− 4.8	13.8	32.9	52.2	71.7	91.4
	1250	− 30.7	− 11.3	7.8	27.5	47.3	67.3	87.6
	1500	− 37.6	− 17.5	2.2	22.3	42.7	63.1	83.9
	1750	− 44.0	− 23.4	− 3.2	17.4	38.2	59.1	80.3
	2000	− 49.0	− 28.9	− 8.2	12.8	34.0	55.3	76.8
	2500	− 60.4	− 38.6	− 17.2	4.5	26.4	48.3	70.4
	3000	− 68.8	− 46.6	− 24.8	− 2.7	19.7	42.0	64.7
				Methane-n-Pentane System				
0.80	0	.....	21.3	37.7	54.4	71.4	88.9	106.7
	100	.....	17.8	35.0	51.8	69.2	87.1	105.2
	200	.....	14.6	32.0	49.4	67.1	85.4	103.5
	400	.....	8.0	26.4	44.7	63.0	81.9	100.4
	600	.....	1.6	20.9	39.9	59.0	78.6	97.4
	800	.....	− 4.6	15.6	35.4	55.3	75.2	94.5
	1000	.....	− 10.7	10.4	30.8	51.5	72.0	91.7
	1250	.....	− 17.7	4.3	25.5	47.0	68.0	88.2
	1500	.....	− 24.2	− 1.9	20.1	42.5	64.1	84.9
	1750	.....	− 30.4	− 7.7	14.8	38.0	60.2	81.5
	2000	.....	− 36.1	− 13.2	9.7	33.5	56.3	78.4
	2500	.....	− 45.9	− 23.1	0.8	24.9	48.9	72.2
	3000	.....	− 54.0	− 31.4	− 7.4	17.3	42.3	66.8
0.90	0	.....	21.3	37.7	54.4	71.4	88.9	106.7
	100	.....	18.8	35.4	52.1	69.3	87.0	104.9
	200	.....	16.3	33.0	50.0	67.3	85.4	103.3
	400	.....	11.0	28.0	45.5	63.3	81.9	100.0
	600	.....	5.7	23.1	41.0	59.4	78.4	96.9
	800	.....	0.1	18.2	36.6	35.6	74.9	93.7
	1000	.....	− 5.7	13.4	32.3	51.8	71.4	90.5
	1250	.....	− 12.8	7.2	26.9	47.0	67.3	86.6
	1500	.....	− 19.7	1.2	21.9	42.4	63.1	82.7
	1750	.....	− 26.0	− 4.5	16.8	37.8	59.0	79.1
	2000	.....	− 31.9	− 9.9	11.9	33.5	55.2	75.8
	2500	.....	− 42.2	− 19.4	3.3	25.6	48.0	69.8
	3000	.....	− 50.4	− 27.4	− 4.4	19.0	41.8	64.6

*—Partial enthalpy, Btu per lb.

necessary to have somewhat detailed information upon which to base predictions and this background should take into account such variables as the temperature, pressure, and composition of the system if satisfactory accuracy is to be attained. Consonant with this approach to the problem of predicting the enthalpies of hydrocarbon mixtures, values of partial enthalpies of the lighter hydrocarbons have been calculated for a number of systems from available experimental data, as functions of temperature, pressure, and composition. Since the composition is capable of almost unlimited variation in mixtures of many components, it has been necessary to consider this variable on a somewhat limited basis until further experimental evidence accumulates.

Tables I to V, inclusive, present such calculated values[14]* of the partial enthalpies of methane, ethane, propane, n-butane, and n-pentane, respectively, in the gas phase of binary mixtures, with corresponding values for the component in the pure state. All of this information is based upon arbitrarily chosen value of zero for the enthalpy at the datum state corresponding to 60°F and infinite volume. For discussions of the accuracy of these data the reader is referred to the original sources as indicated by the literature references for each case. In general, these partial enthalpies of the components in the gas phase were established from volumetric and Joule-Thomson measurements together with determinations of the heat capacity of the gas at low pressures.

In Table VI are recorded partial enthalpy values for methane in the liquid phase for the methane-n-butane, methane-n-pentane, and the methane-crystal oil systems. The data for the first two of these systems were calculated from available information[15,16,17] concerning the volumetric behavior of these systems combined with published enthalpy data for methane at infinite volume.[16] The values of partial enthalpy for methane in the methane-crystal oil system were published earlier.[18]**

Table VII gives the enthalpy of

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TABLE II
PARTIAL ENTHALPIES OF ETHANE IN THE GAS PHASE

Weight Fraction Ethane	Pressure lb./sq. in. Absolute	70° F.	100° F.	130° F.	160° F.	190° F.	220° F.	250° F.
				Pure Ethane				
1.00	0	4.1*	16.9	30.1	43.9	58.1	72.7	87.9
	100	− 0.9	12.1	25.6	39.8	54.5	69.6	85.1
	200	− 6.9	6.6	20.9	35.5	50.6	66.3	82.3
	400	− 23.0	− 6.4	9.8	25.6	41.9	58.8	76.2
	600	.....	− 24.0	− 5.4	13.7	32.0	50.5	69.9
	800	.....	− 51.4	− 27.4	− 1.0	20.4	41.7	63.2
	1000	.....	−110.9	− 55.4	− 19.3	8.1	32.1	56.3
	1250	.....	−116.9	− 87.0	− 47.8	− 10.6	19.0	47.0
	1500	.....	−120.3	− 95.5	− 65.1	− 29.0	5.6	37.3
	1750	.....	−122.4	−100.0	− 74.6	− 41.9	− 6.7	28.4
	2000	.....	−123.6	−103.0	− 80.1	− 50.8	− 16.4	20.8
	2500	.....	.....	−106.9	− 86.2	− 60.6	− 28.3	9.7
	3000	.....	.....	−109.1	− 89.2	− 65.4	− 34.4	2.9
				Methane-Ethane System				
0.00	0	4.1	16.9	30.1	43.9	58.1	72.7	87.9
	100	0.1	13.3	27.0	40.9	55.4	70.1	85.5
	200	− 4.4	9.4	23.5	37.8	52.5	67.5	83.0
	400	− 14.2	1.2	16.2	31.3	46.6	62.1	77.8
	600	− 25.1	− 7.8	8.4	24.4	40.4	56.4	72.5
	800	− 36.7	− 17.4	0.2	17.3	33.9	50.4	66.9
	1000	− 48.8	− 27.4	− 8.2	9.9	27.2	44.2	61.4
	1250	− 64.6	− 40.1	− 18.9	0.5	18.7	36.5	54.3
	1500	− 80.2	− 52.6	− 29.4	− 8.9	10.3	28.7	47.0
	1750	− 95.0	− 64.5	− 39.5	− 17.8	2.2	21.1	39.8
	2000	−108.3	− 75.6	− 48.9	− 26.1	− 5.5	13.8	32.6
	2500	−129.9	− 94.0	− 65.1	− 40.8	− 19.5	0.0	18.6
	3000	−144.1	−106.9	− 77.3	− 52.7	− 31.5	− 12.4	5.5
0.20	0	4.1	16.9	30.1	43.9	58.1	72.7	87.9
	100	− 0.1	13.3	26.8	40.8	55.3	70.0	85.5
	200	− 4.8	9.3	23.4	37.5	52.3	67.3	82.9
	400	− 15.1	0.5	15.8	30.7	46.1	61.7	77.5
	600	− 26.5	− 9.1	7.5	23.6	39.7	55.8	72.3
	800	− 39.3	− 19.4	− 1.2	16.2	32.9	49.7	66.5
	1000	− 52.7	− 30.4	− 10.1	8.2	26.1	43.5	60.8
	1250	− 70.5	− 44.5	− 21.5	− 1.6	17.4	35.7	53.5
	1500	− 88.4	− 58.8	− 33.0	− 11.2	8.9	28.0	46.1
	1750	−105.0	− 72.7	− 44.1	− 20.4	0.8	20.3	38.8
	2000	−119.1	− 85.0	− 54.4	− 29.1	− 7.0	12.9	31.5
	2500	−137.0	−102.7	− 70.7	− 44.3	− 21.3	− 0.9	17.5
	3000	−145.0	−112.0	− 81.2	− 55.6	− 33.2	− 13.7	4.8
0.40	0	4.1	16.9	30.1	43.9	58.1	72.7	87.9
	100	− 0.4	12.8	26.5	40.5	55.1	69.9	85.4
	200	− 5.5	8.5	22.6	37.0	51.9	67.1	82.9
	400	− 16.9	1.2	14.2	29.7	45.3	61.3	77.5
	600	− 30.3	− 11.9	4.8	21.6	38.1	54.9	71.9
	800	− 44.7	− 28.5	− 5.0	13.0	30.5	48.3	66.1
	1000	− 60.3	− 35.8	− 15.4	4.1	22.6	41.4	60.2
	1250	− 79.2	− 50.8	− 28.3	− 7.4	12.5	32.7	52.9
	1500	− 95.4	− 64.8	− 40.9	− 18.9	2.3	24.0	45.6
	1750	−107.3	− 76.7	− 52.6	− 30.1	− 7.7	15.5	38.4
	2000	−114.9	− 86.0	− 62.9	− 40.5	− 17.1	7.3	31.3
	2500	−121.4	− 97.9	− 78.6	− 57.5	− 33.1	− 7.1	18.2
	3000	−122.7	−103.5	− 92.7	− 68.3	− 44.8	− 18.9	6.6
0.60	0	4.1	16.9	30.1	43.9	58.1	72.7	87.9
	100	− 0.9	12.3	26.2	40.4	54.9	69.8	85.1
	200	− 6.5	7.8	22.0	36.8	51.5	66.8	82.4
	400	− 19.9	− 3.3	12.4	28.6	44.4	60.3	76.5
	600	− 36.5	− 16.6	1.3	19.7	36.5	53.1	70.3
	800	− 56.0	− 32.0	− 11.0	12.3	27.7	45.7	63.7
	1000	− 76.7	− 48.6	− 24.2	− 1.2	18.6	37.9	57.1
	1250	−102.3	− 68.9	− 41.1	− 15.7	6.6	28.0	48.7
	1500	−120.1	− 86.8	− 57.4	− 30.3	− 5.4	18.1	40.5
	1750	−129.1	−100.8	− 71.9	− 43.9	− 16.8	8.6	32.4
	2000	−133.4	−110.7	− 83.8	− 58.1	− 27.0	− 0.4	24.6
	2500	−134.7	−120.2	− 97.8	− 73.8	− 42.9	− 16.0	8.5
	3000	−132.3	−121.8	−103.0	− 81.8	− 53.0	− 26.7	− 2.0
0.80	0	4.1	16.9	30.1	43.9	58.1	72.7	87.9
	100	0.0	12.2	28.1	40.2	54.6	69.7	85.1
	200	− 4.8	7.1	21.4	36.2	51.0	66.4	82.1
	400	− 8.5	− 5.4	10.9	27.1	42.8	59.2	75.9
	600	− 40.4	− 21.4	− 2.0	16.2	33.7	51.1	69.1
	800	− 68.0	− 41.6	− 17.3	4.0	23.4	42.6	61.8
	1000	.....	− 65.0	− 34.3	− 9.5	12.4	33.5	54.1
	1250	.....	− 97.2	− 57.0	− 26.8	− 1.8	21.9	44.4
	1500	.....	−124.5	− 77.9	− 43.2	− 15.3	10.7	34.8
	1750	.....	−141.5	− 93.9	− 57.1	− 27.2	0.4	25.7
	2000	.....	−150.2	−104.2	− 67.5	− 37.0	− 8.8	17.3
	2500	.....	−155.6	−113.8	− 79.7	− 50.4	− 22.7	3.5
	3000	.....	−155.4	−116.7	− 84.9	− 57.5	− 30.9	− 5.6

*—Partial enthalpy, Btu per lb.

pure ethane and the partial enthalpy of ethane in the liquid phase of the ethane-crystal oil system. The enthalpy of pure ethane[19] was employed in conjunction with the change in partial enthalpy upon solution of ethane in crystal oil[12] to determine the partial enthalpy of ethane in the liquid phase. In this instance the partial enthalpy has been recorded only for the bubble-point state and the influence of pressure under conditions of constant temperature and composition has not been indicated. Similar information for pure propane[20] and propane in the liquid phase of the propane-crystal oil system[12] is presented in Table VIII. Correspondingly Table IX contains the enthalpy of pure n-butane[21] and values of the partial enthalpy of n-butane in the liquid phase of the methane-n-butane system. The latter information was computed from published data concerning the volumetric and phase behavior of the methane-n-butane system[15,16] in combination with the available information concerning the enthalpy of n-butane at infinite volume.[16]

The enthalpy of pure n-pentane in the liquid phase[22,23] is recorded in Table X together with the partial enthalpy of n-pentane in the liquid phase of the methane-n-pentane system. These latter data were obtained from information regarding the volumetric and phase behavior of the methane-n-pentane system[17] combined with published values of the heat capacity of n-pentane at infinite volume.[24] All the partial enthalpies in the liquid phase recorded in Tables VI to X, inclusive, are based

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TABLE III
PARTIAL ENTHALPIES OF PROPANE IN THE GAS PHASE

Weight Fraction Propane	Pressure lb./sq. in. Absolute	70° F.	100° F.	130° F.	160° F.	190° F.	220° F.	250 °F.
				Pure Propane				
1.0	0	4.0*	16.1	28.6	41.5	54.7	68.3	82.2
	100	− 5.4	7.6	21.3	35.2	49.5	63.4	77.9
	200	.....	.....	11.5	27.0	42.4	57.7	73.0
	400	.....	.....	.....	.....	23.0	42.4	.....
				Methane-Propane System				
0.00	0	4.0	16.1	28.6	41.5	54.7	68.3	82.2
	200	− 7.7	6.1	19.9	33.4	47.0	61.5	76.1
	400	− 20.6	− 4.8	10.5	24.8	39.0	54.4	69.7
	600	− 35.1	− 16.8	0.3	15.8	30.7	47.1	63.1
	800	− 51.2	− 30.2	− 10.7	6.2	22.3	39.9	56.6
	1000	− 69.6	− 45.3	− 23.1	− 4.1	13.9	32.6	50.1
	1250	.....	− 68.1	− 40.9	− 18.1	3.5	23.9	42.5
	1500	.....	− 98.1	− 61.9	− 33.2	− 6.8	15.8	35.4
0.20	0	4.0	16.1	28.6	41.5	54.7	68.3	82.2
	200	− 8.0	5.9	19.6	33.2	46.8	61.4	76.0
	400	− 21.2	− 5.3	9.9	24.5	38.7	54.1	69.4
	600	− 36.1	− 17.5	− 0.6	15.3	30.4	46.7	62.7
	800	− 52.6	− 30.7	− 11.8	5.9	22.1	39.2	56.1
	1000	− 70.8	− 44.9	− 23.4	− 3.6	13.7	31.9	49.6
	1250	− 95.6	− 63.4	− 38.1	− 15.3	3.4	23.0	41.8
	1500	−122.8	− 82.5	− 52.9	− 26.4	− 6.4	14.4	34.5
0.40	0	4.0	16.1	28.6	41.5	54.7	68.3	82.2
	200	− 8.7	5.6	18.9	32.9	46.9	61.1	75.6
	400	− 22.9	− 6.1	8.3	23.7	38.6	53.5	68.6
	600	− 38.6	− 18.6	− 2.7	14.1	30.0	45.8	61.5
	800	− 55.9	− 31.6	− 13.7	4.5	21.4	37.9	54.2
	1000	.....	− 44.4	− 24.2	− 4.9	12.8	30.1	47.0
	1250	.....	− 59.0	− 35.8	− 15.8	2.6	20.6	38.2
	1500	.....	.....	− 45.1	− 25.3	− 6.6	11.8	29.9
0.60	0	4.0	16.1	28.6	41.5	54.7	68.3	82.2
	200	− 11.6	3.2	17.3	31.0	45.7	60.2	74.6
	400	− 30.3	− 12.3	3.8	18.8	35.2	51.2	66.0
	600	.....	.....	− 11.2	5.5	23.2	41.4	56.5
	800	.....	.....	.....	− 8.4	10.1	30.8	46.2
	1000	.....	.....	.....	− 22.7	− 3.1	19.9	35.2
	1250	.....	.....	.....	.....	− 17.9	6.4	21.2
	1500	.....	.....	.....	.....	− 29.9	− 5.9	7.5

*—Partial enthalpy, Btu per lb.

upon a value of zero for the partial enthalpy of the component in question at the datum state corresponding to 60°F and infinite volume.

Most hydrocarbon systems of industrial interest contain material of molecular weight higher than that of n-pentane. The thermodynamic properties of a water-white, highly refined oil, here called crystal oil, have been investigated[25] and Table XI gives values of the enthalpy of this material in the pure state as a function of pressure and temperature. In this case the datum state has necessarily been changed from 60°F and infinite volume to 60°F and bubble-point pressure. In addition the enthalpies of two crude oils have been determined as functions of temperature and pressure.[26,27] The enthalpies of these two crude oils are also included in Table XI. It should be emphasized that the reference state for the enthalpies of these oils is quite different from that for the enthalpies of the lighter hydrocarbons recorded in Tables I to X, inclusive. Furthermore, the application of these enthalpy data will cause some uncertainty since they represent only the enthalpies of the oils in the "pure" state. Moreover, it is necessary for the use of these data in connection with heterogeneous mixtures that no appreciable part of these constituents is transferred to the gas phase. Under such conditions the use of different datum states does not affect the result of the calculations. The partial enthalpies do not appear to change markedly with respect to composition in the case of the heavier components in the liquid phase when they are present in high concentrations. Therefore, until additional information is available, they may be tentatively utilized.

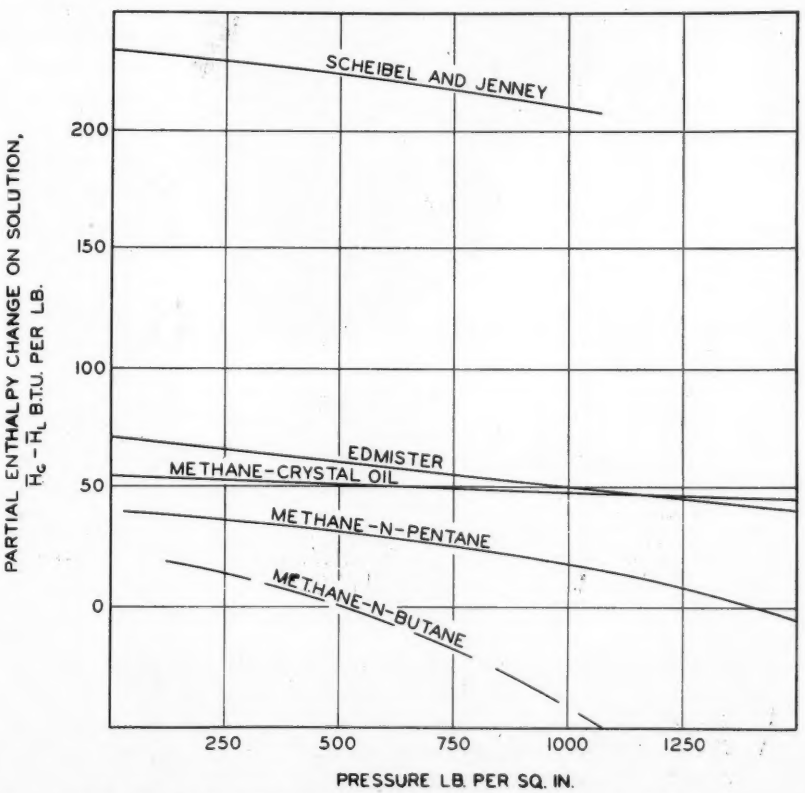

Fig. 2. Change in Partial Enthalpy as a Result of the Solution of Methane.

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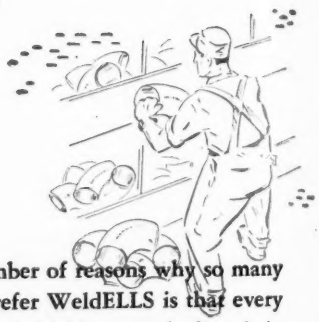

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TABLE IV
PARTIAL ENTHALPIES OF N-BUTANE IN THE GAS PHASE

Weight Fraction n-Butane	Pressure lb./sq. in. Absolute	70° F.	100° F.	130° F.	160° F.	190° F.	220° F.	250° F.
				Pure n-Butane				
1.0	0	3.9*	15.7	27.9	40.4	53.3	66.6	80.3
	100	.....	.....	.....	31.8	46.1	60 5	74.9
	200	.....	.....	.....	....	....	51.6	67.2
				Methane-n-Butane System				
0.00	0	3.9	15.7	27.9	40.4	53.3	66.6	80.3
	100	0.9	12.9	25.4	38.1	51.3	64.7	78.5
	200	− 2.2	10.0	22.7	35.7	49.0	62.6	76.6
	400	− 8.6	3.9	16.8	30.0	43.7	57.4	71.7
	600	− 14.6	− 2.4	10.3	23.5	37.3	51.1	65.7
	800	− 19.4	− 8.7	3.3	16.0	29.8	43.6	58.4
	1000	− 22.9	− 14.8	− 4.0	7.7	21.2	35.1	50.2
	1250	− 25.8	− 21.9	− 13.5	− 3.3	9.4	23.2	39.2
	1500	− 27.6	− 28.5	− 23.0	− 14.6	− 2.7	10.8	27.8
	1750	− 28.7	− 34.7	− 32.2	− 25.8	− 14.6	− 1.2	16.7
	2000	− 29.7	− 40.5	− 40.7	− 35.9	− 25.3	− 11.5	6.9
	2500	− 33.3	− 51.3	− 55.5	− 51.6	− 41.5	− 27.2	− 8.4
	3000	− 42.7	− 61.7	− 66.7	− 62.5	− 52.4	− 37.4	− 18.2
0.10	0	3.9	15.7	27.9	40.4	53.3	66.6	80.3
	100	0.2	12.3	24.7	37.6	50.8	64.4	78.2
	200	− 3.5	8.7	21.4	34.6	48.1	61.9	75.9
	400	− 11.5	1.2	14.4	28.1	42.1	56.3	70.6
	600	− 19.5	− 6.5	6.8	20.9	35.2	49.9	64.5
	800	− 27.1	− 14.4	− 1.1	13.2	27.8	42.8	57.7
	1000	− 34.4	− 22.2	− 9.2	5.2	20.0	35.3	50.4
	1250	− 42.2	− 31.5	− 19.2	− 4.9	9.9	25.6	41.0
	1500	− 48.8	− 40.3	− 29.0	− 15.0	0.0	15.9	31.6
	1750	− 54.5	− 48.4	− 38.3	− 24.7	− 9.5	6.7	22.6
	2000	− 59.8	− 55.9	− 47.0	− 33.7	− 18.3	− 1.8	14.4
	2500	− 67.8	− 69.2	− 62.0	− 48.9	− 32.9	− 15.8	0.9
	3000	− 77.0	− 80.1	− 73.2	− 59.6	− 43.2	− 25.2	− 7.7
0.20	0	3.9	15.7	27.9	40.4	53.3	66.6	80.3
	100	− 0.9	11.4	24.0	37.1	50.5	64.1	78.0
	200	− 5.8	6.8	20.0	33.6	47.5	61.4	75.6
	400	− 15.7	− 2.6	12.5	26.1	41.0	55.5	70.0
	600	− 25.7	− 12.2	3.6	18.1	33.8	48.9	64.0
	800	− 35.5	− 21.9	− 5.6	9.6	26.2	41.9	57.5
	1000	− 44.9	− 31.5	− 14.9	1.0	18.2	34.5	50.6
	1250	− 55.7	− 42.8	− 26.3	− 9.7	8.2	25.2	41.9
	1500	− 65.4	− 53.4	− 37.3	− 20.0	− 1.4	16.1	33.3
	1750	− 73.9	− 63.0	− 47.5	− 29.6	− 10.4	7.6	25.2
	2000	− 81.2	− 71.7	− 56.7	− 38.2	− 18.5	− 0.2	17.8
	2500	− 92.7	− 85.9	− 72.0	− 52.4	− 31.6	− 12.8	5.6
	3000	−101.0	− 96.0	− 82.8	− 62.7	− 40.8	− 21.8	− 2.8
0.30	0	3.9	15.7	27.9	40.4	53.3	66.6	80.3
	100	− 2.0	10.4	23.1	36.2	49.5	63.2	77.1
	200	− 8.0	4.9	18.2	31.8	45.6	59.6	73.8
	400	− 20.4	− 6.6	7.8	22.9	37.6	52.0	66.7
	600	.....	− 18.3	− 2.7	13.9	29.3	44.1	59.3
	800	.....	− 29.7	− 12.9	4.8	20.9	36.1	51.7
	1000	.....	− 40.5	− 22.6	− 4.0	12.7	28.1	44.0
	1250	.....	− 53.0	− 33.7	− 14.5	2.7	18.4	34.6
	1500	.....	− 64.1	− 43.9	− 24.1	− 6.6	9.2	25.6
	1750	.....	− 73.7	− 52.9	− 32.8	− 15.1	0.8	17.2
	2000	.....	− 81.8	− 60.7	− 40.4	− 22.7	− 6.8	9.7
	2500	.....	− 92.8	− 72.5	− 52.6	− 34.9	− 19.0	− 2.6
	3000	.....	− 97.3	− 79.4	− 60.8	− 43.2	− 27.4	− 10.8
0.40	0	3.9	15.7	27.9	40.4	53.3	66.6	80.3
	100	.....	9.2	21.6	34.3	47.5	61.2	75.4
	200	.....	2.9	15.3	28.2	41.5	55.7	70.5
	400	.....	− 9.2	2.9	15.9	29.7	44.6	60.4
	600	.....	.....	− 9.1	3.9	18.0	33.5	50.3
	800	.....	.....	− 20.2	− 7.5	6.8	22.6	40.3
	1000	.....	.....	− 30.3	− 18.0	− 3.8	12.1	30.6
	1250	.....	.....	− 41.2	− 29.6	− 15.9	− 0.2	18.9
	1500	.....	.....	− 50.1	− 39.5	− 26.7	− 11.4	8.0
	1750	.....	.....	− 57.1	− 47.8	− 35.9	− 21.2	− 1.7
	2000	.....	.....	− 62.5	− 54.6	− 43.7	− 29.6	− 10.3
	2500	.....	.....	− 68.9	− 63.9	− 55.0	− 42.3	− 23.8
	3000	.....	.....	− 69.8	− 68.0	− 61.3	− 50.3	− 32.6

*—Partial enthalpy, Btu per lb.

Many conditions of industrial interest are not even closely approximated by the states recorded in Tables I to X. Rough estimation of the partial enthalpies for conditions not covered by the tables may be accomplished by linear isobaric-isothermal interpolation or, if necessary, limited extrapolation. However, the further the conditions in question deviate from those recorded, the larger is the probable uncertainty in the estimated results.

In order to show the variation in behavior of a component in different environments, Figure 2 presents the difference between the partial enthalpy of methane in the gas phase and that in the liquid phase as a function of pressure at 160°F in the methane-n-butane, methane-n-pentane, and methane-crystal oil systems. In addition there has been shown the result of prediction by means of the nomograph of Scheibel and Jenny.[11]

Applications

In order to illustrate the use of the partial enthalpy data in Tables I to XI, the enthalpies of several mixtures of hydrocarbons at specified states are calculated and enthalpy values are utilized in a problem in the steady flow of a heterogeneous fluid involving changes in state.

The enthalpy of a phase may be estimated from the partial enthalpies of the components[10,16] by application of the following expression:

$$H = \sum_{k=1}^{k=n} H_k n_k \qquad (1)$$

Equation 1 gives exact results when the partial enthalpy values used are applicable. The data recorded in Tables I to XI are limited in regard to their application since they describe accurately only the partial enthalpies of the components in the systems indicated. For present purposes it is usually sufficient to approximate the partial enthalpy of a component in a multicomponent system for a particular pressure, temperature, and composition by using

TABLE V
PARTIAL ENTHALPIES OF N-PENTANE IN THE GAS PHASE

				Pure n-Pentane				
1.0	0	3.5*	15.4	27.3	39.7	52.5	65.6	79.4
	100	.....	.....	.....	.....	.....	.....	70.5
				Methane-n-Pentane System				
0.0	0	.....	15.4	27.3	39.7	52.5	65.6	79.4
	100	.....	3.3	17.0	30.9	45.9	60.7	75.8
	200	.....	− 7.5	6.8	22.1	39.2	55.8	72.3
	400	.....	− 27.9	− 12.2	5.6	26.3	46.4	65.6
	600	.....	− 45.8	− 29.3	− 9.6	14.2	37.4	59.3
	800	.....	− 61.6	− 44.8	− 23.6	2.5	29.0	53.3
	1000	.....	− 75.7	− 58.2	− 36.4	− 8.4	21.1	47.8
	1250	.....	− 91.5	− 74.2	− 51.3	− 21.5	11.6	41.5
	1500	.....	−105.2	− 87.7	− 64.6	− 33.5	2.8	35.7
	1750	.....	−117.0	− 99.8	− 76.9	− 44.7	− 5.0	30.5
	2000	.....	−127.5	−110.5	− 87.9	− 54.9	− 12.1	25.8
	2500	.....	−145.4	−129.0	−106.5	− 72.6	− 25.6	17.7
	3000	.....	−160.6	−144.4	−121.9	− 87.6	− 37.4	10.7
0.10	0	.....	15.4	27.3	39.7	52.5	65.6	79.4
	100	.....	7.0	19.8	32.5	46.2	60.4	75.2
	200	.....	− 0.9	12.2	25.4	39.9	54.7	71.2
	400	.....	− 16.6	− 2.6	12.1	28.0	44.7	63.4
	600	.....	− 31.7	− 16.6	− 0.6	16.8	35.4	55.6
	800	.....	− 45.7	− 29.8	− 12.3	6.0	26.4	48.4
	1000	.....	− 58.1	− 41.7	− 23.2	− 3.9	17.9	41.5
	1250	.....	− 71.5	− 54.8	− 36.3	− 15.8	7.7	33.2
	1500	.....	− 82.7	− 66.4	− 47.5	− 26.6	− 1.8	25.6
	1750	.....	− 92.2	− 76.4	− 57.8	− 36.5	− 10.4	18.6
	2000	.....	−100.3	− 85.4	− 67.3	− 45.5	− 18.4	12.4
	2500	.....	−112.9	−100.3	− 83.1	− 60.6	− 31.8	1.6
	3000	.....	−122.0	−110.5	− 94.1	− 71.5	− 41.6	− 7.4
0.20	0	.....	15.4	27.3	39.7	52.5	65.6	79.4
	100	.....	10.0	22.4	34.8	47.4	60.7	75.2
	200	.....	4.7	17.4	29.7	42.3	55.9	70.9
	400	.....	− 6.0	6.7	19.3	32.0	46.4	62.3
	600	.....	− 16.8	− 4.2	8.6	21.6	36.7	53.6
	800	.....	− 27.8	− 15.2	− 2.2	11.5	26.9	45.0
	1000	.....	− 38.2	− 25.9	− 12.7	1.4	17.4	36.5
	1250	.....	− 50.7	− 38.7	− 25.4	− 10.7	6.0	26.3
	1500	.....	− 62.3	− 50.2	− 36.7	− 21.9	− 4.4	16.6
	1750	.....	− 72.4	− 60.0	− 46.5	− 31.5	− 13.5	7.8
	2000	.....	− 80.8	− 68.0	− 54.5	− 39.4	− 21.3	0.0
	2500	.....	− 92.9	− 79.6	− 65.6	− 50.5	− 33.0	− 12.6
	3000	.....	− 99.4	− 86.3	− 72.4	− 57.6	− 41.1	− 22.0

*—Partial enthalpy, Btu per lb.

TABLE VI
PARTIAL ENTHALPIES OF METHANE IN LIQUID PHASE

Weight Fraction Methane	Pressure lb./sq. in. Absolute	70° F.	100° F.	130° F.	160° F.	190° F.	220° F.	250° F.
				Methane-n-Butane System				
0.0		(31.3)*	(51.5)	(80.8)	(121.0)	(174.4)	(243.5)	(330.4)
	Bu. P.	− 98	− 52	− 7	34	78	131	191
	100	− 99	− 53	− 8	.....	.....	.....	.....
	200	−100	− 55	− 11	30	76	.....	.....
	400	−101	− 57	− 16	21	61	109	169
	600	−102	− 59	− 21	13	49	87	127
	800	−102	− 61	− 25	8	40	70	99
	1000	−103	− 63	− 28	3	32	57	78
	1250	−104	− 65	− 31	− 2	24	44	58
	1500	−104	− 67	− 34	− 5	18	34	44
	1750	−105	− 68	− 36	− 8	13	26	33
	2000	−105	− 69	− 37	− 10	10	21	25
	2500	−105	− 70	− 39	− 13	5	14	14
	3000	−105	− 71	− 40	− 15	3	10	8
0.1		(819)	(900)	(980)	(1048)	(1111)	(1167)	(1173)
	Bu. P.	− 80	− 27	30	90	160	246	347
	1000	− 85	− 30	29	.....	.....	.....	.....
	1250	− 90	− 38	18	77	145	230	324
	1500	− 94	− 43	10	64	124	193	266
	1750	− 96	− 47	4	54	107	165	224
	2000	− 98	− 50	− 1	46	94	144	194
	2500	−101	− 55	− 8	35	76	115	152
	3000	−103	− 57	− 12	30	67	99	127
0.2		(1393)	(1435)	(1565)	(1611)	(1620)	.....	.....
	Bu. P.	− 54	0	60	126	205	.....	.....
	1500	− 59	− 4	.....	.....	.....	.....	.....
	1750	− 68	− 14	46	110	186	.....	.....
	2000	− 75	− 23	32	90	158	.....	.....
	2500	− 85	− 36	13	64	124	.....	.....
	3000	− 91	− 44	2	49	105	.....	.....
0.3		(1745)	(1796)	.....	.....	.....	.....	.....
	Bu. P.	− 27	22	.....	.....	.....	.....	.....
	1750	− 28	.....	.....	.....	.....	.....	.....
	2000	− 40	9	.....	.....	.....	.....	.....
	2500	− 56	− 12	.....	.....	.....	.....	.....
	3000	− 66	− 24	.....	.....	.....	.....	.....

*—Figures in parentheses indicate bubble-point pressures in pounds per square inch, absolute.

a value taken from the appropriate table for the state in question. The system chosen should involve another component which has as nearly as possible the same molecular weight as the average value for all the other components of the multicomponent system. For example, if the average molecular weight of all the components of multicomponent systems other than methane is relatively high, the partial enthalpy values for methane in the methane-crystal oil system are more suitable than those for methane in binary systems with components of lower molecular weight. When a component is present in large concentrations it is often satisfactory to use the enthalpy of the pure component, if the state is such that the pure component would be stable in the phase in question. If desired the partial enthalpies of components of

TABLE VI
PARTIAL ENTHALPIES OF METHANE IN LIQUID PHASE (Continued)

Weight Fraction Methane	Pressure lb./sq. in. Absolute	70° F.	100° F.	130° F.	160° F.	190° F.	220° F.	250° F.
			Methane-n-Pentane System					
0.0		.....	(15.7)*	(26.5)	(42.5)	(64.9)	.....	.....
	Bu. P.	.....	− 37.0	− 24.0	13.0	77.0	.....	.....
	100	.....	− 37.2	− 24.4	12.3	76.2	.....	.....
	200	.....	− 37.3	− 24.9	11.1	73.8	.....	.....
	400	.....	− 37.7	− 25.8	8.8	69.4	.....	.....
	600	.....	− 38.0	− 26.7	6.7	65.2	.....	.....
	800	.....	− 38.4	− 27.6	4.7	61.3	.....	.....
	1000	.....	− 38.7	− 28.4	2.9	57.7	.....	.....
	1250	.....	− 39.1	− 29.4	0.9	53.7	.....	.....
	1500	.....	− 39.4	− 30.3	− 1.0	50.3	.....	.....
	1750	.....	− 39.8	− 31.1	− 2.5	47.5	.....	.....
	2000	.....	− 40.0	− 31.8	− 3.9	45.2	.....	.....
	2500	.....	− 40.6	− 33.0	− 6.1	41.8	.....	.....
	3000	.....	− 41.1	− 34.0	− 7.8	39.4	.....	.....
0.1		.....	(1093)	(1165)	(1230)	(1282)	(1316)	(1331)
	Bu. P.	.....	− 39.0	− 21.0	14.0	61.0	121.0	222.0
	1250	.....	− 40.9	− 22.5	13.4	.....	.....	.....
	1500	.....	− 43.5	− 26.6	6.4	50.7	106.1	195.8
	1750	.....	− 45.8	− 30.1	0.5	41.1	90.0	167.9
	2000	.....	− 47.8	− 33.1	− 4.4	33.3	77.7	148.4
	2500	.....	− 50.8	− 37.8	− 11.8	22.1	60.9	123.3
	3000	.....	− 52.7	− 41.1	− 16.8	14.8	50.3	108.5
0.2		.....	(1840)	(1910)	(1951)	(1962)	(1934)	.....
	Bu. P.	.....	− 17.0	8.0	45.0	105.0	185.0	.....
	2000	.....	− 21.7	4.8	42.8	102.7	179.2	.....
	2500	.....	− 32.7	8.9	24.9	79.4	147.5	.....
	3000	.....	− 39.7	17.8	13.5	64.8	128.8	.....
0.3		.....	(2211)	(2250)	(2240)	(2168)	.....	.....
	Bu. P.	.....	− 1.0	29.0	114.0	191.0	.....	.....
	2500	.....	− 9.7	18.5	100.8	172.6	.....	.....
	3000	.....	− 21.0	4.4	84.0	153.5	.....	.....

*—Figures in parentheses indicate bubble-point pressures in pounds per square inch, absolute.

Methane-Crystal Oil System
Bubble Point Condition Only

0.0	.....	.....	(0)*	(0)	(0)	(0)	(0)	.....
	.....	.....	− 25.5	− 13.6	− 1.0	12.2	26.0	.....
0.01	.....	.....	(570)	(592)	(614)	(636)	(658)	.....
	.....	.....	− 37.0	− 23.2	− 9.1	5.0	19.4	.....
0.02	.....	.....	(1110)	(1154)	(1200)	(1242)	(1288)	.....
	.....	.....	− 48.8	− 33.3	− 18.2	− 3.3	12.1	.....
0.03	.....	.....	(1604)	(1676)	(1748)	(1818)	(1886)	.....
	.....	.....	− 60.5	− 44.1	− 28.1	− 12.0	3.5	.....
0.04	.....	.....	(2040)	(2141)	(2238)	(2333)	(2435)	.....
	.....	.....	− 72.0	− 55.0	− 38.5	− 22.4	− 6.7	.....
0.05	.....	.....	(2420)	(2545)	(2672)	(2798)	(2924)	.....
	.....	.....	− 83.5	− 65.7	− 49.0	− 33.6	− 19.0	.....
0.06	.....	.....	(2767)	(2921)	(3076)	(3229)	(3375)	.....
	.....	.....	− 95.0	− 75.9	− 59.5	− 45.3	− 33.0	.....

*—Figures in parentheses indicate bubble-point pressures in pounds per square inch, absolute.

TABLE VII
PARTIAL ENTHALPIES OF ETHANE IN LIQUID PHASE

Weight Fraction Ethane	Pressure lb./sq. in. Absolute	70° F.	100° F.	130° F.	160° F.	190° F.	220° F.	250° F.
			Pure Ethane					
1.0		(566.0)*	.....	.....	.....	.....	.....	.....
	100	.....	.....	.....	.....	.....	.....	.....
	200	.....	.....	.....	.....	.....	.....	.....
	400	.....	.....	.....	.....	.....	.....	.....
	600	−130.7	.....	.....	.....	.....	.....	.....
	800	−133.6	.....	.....	.....	.....	.....	.....
	1000	−135.4	.....	.....	.....	.....	.....	.....
			Ethane-Crystal Oil System					
			Bubble Point Conditions Only					
0.0	.....	.....	(0)	.....	(0)	.....	.....	.....
	.....	.....	−153.3	.....	−124.4	.....	.....	.....
0.025	.....	.....	(148)	.....	(205)	.....	.....	.....
	.....	.....	−152.8	.....	−121.2	.....	.....	.....
0.050	.....	.....	(240)	.....	(360)	.....	.....	.....
	.....	.....	−150.9	.....	−117.2	.....	.....	.....
0.075	.....	.....	(328)	.....	(507)	.....	.....	.....
	.....	.....	−147.6	.....	−114.5	.....	.....	.....
0.100	.....	.....	(410)	.....	(643)	.....	.....	.....
	.....	.....	−150.6	.....	−112.3	.....	.....	.....
0.125	.....	.....	(482)	.....	(770)	.....	.....	.....
	.....	.....	−151.4	.....	−111.3	.....	.....	.....

*—Figures in parentheses indicate bubble-point pressures in pounds per square inch, absolute.

multicomponent systems may be estimated from linear interpolations of the tabular data on the basis of the average molecular weight of the other components making up the system. However, for most purposes a relatively simple inspection of the tabular data will reveal the most applicable data to use.

In Table XII are recorded the enthalpies for several hydrocarbon mixtures both in the gas and the liquid phase. It is necessary to determine whether the system is in the liquid phase, the gas phase, or the heterogeneous region before the enthalpy can be evaluated. This information can usually be obtained from available correlations[28] of the phase behavior of hydrocarbon systems of application of established techniques.[29]

If the system is homogeneous the enthalpy may be predicted from

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Equation 1, utilizing the partial enthalpies recorded in Tables I to XI as outlined above. If the system is in a heterogeneous state the enthalpy of the mixture may be determined from the enthalpies of the phases and the quality n_g by use of the following expression:

$$H'' = H_g n_g + H_l n_l = n_g \sum_{k=1}^{k=n} H_{k_g} n_{k_g} + (1 - n_g) \sum_{k=1}^{k=n} H_{k_l} n_{k_l} \qquad (2)$$

All the systems included in Table XII were homogeneous at the states in question and therefore Equation 2 was not needed in those cases.

In order to illustrate the utility of the tabulated enthalpy data in steady-flow processes the following example may be considered. A mixture of methane, propane, n-pentane, and crystal oil of the composition shown in a part of Table XIII enters a heater and separator at a temperature of 100°F and a pressure of 1000 pounds per square inch. The system is liquid under these circumstances and the enthalpy as computed is -32.2 B.t.u. per pound.

Liquid and gas phases are withdrawn at different outlets from the separator and heater at a temperature of 220°F and a pressure of 1000 pounds per square inch. It is desired to determine the heat requirement for a total flow rate of 1000 pounds per hour. By application of the available[28] equilibrium constant data in accordance with established techniques[29] the composition and relative amounts of the gas and liquid phases withdrawn from the separator can be determined. The results of such calcula-

TABLE VIII
PARTIAL ENTHALPIES OF PROPANE IN LIQUID PHASE

Weight Fraction Propane	Pressure lb./sq. in. Absolute	70° F.	100° F.	130° F.	160° F.	190° F.	220° F.	250° F.
				Pure Propane				
1.0	200	−158.0	−138.6	.....	.....	.....	.....	.....
	400	−158.0	−138.8	−118.1	− 94.6	.....	.....	.....
	600	−157.9	−138.9	−118.7	− 97.0	− 70.9	.....	.....
	800	−157.8	−138.9	−119.1	− 98.1	− 75.3	.....	.....
	1000	−157.6	−138.8	−119.3	− 98.9	− 77.6	.....	.....
	1250	−157.4	−138.7	−119.3	− 99.5	− 79.3	.....	.....
	1500	−157.1	−138.5	−119.3	− 99.9	− 80.3	.....	.....
	1750	−156.7	−138.3	−121.3	−100.0	− 80.9	− 61.8	.....
	2000	−156.4	−138.0	−119.1	−100.1	− 81.3	− 62.8	.....
	2500	−155.5	−137.2	−118.6	− 99.8	− 81.9	− 63.8	− 45.2
	3000	−154.6	−136.4	−117.8	− 99.2	− 81.2	− 64.0	− 46.1
				Propane-Crystal Oil System				
				Bubble Point Conditions Only				
0.0	.....	.....	(0)*	(0)	(0)	(0)	(0)	.....
	.....	.....	−140.7	−123.0	−105.1	− 87.0	− 69.1	.....
0.2	.....	.....	(115)	(131)	(220)	(293)	(388)	.....
	.....	.....	−142.0	−124.1	−105.6	− 87.2	− 68.9	.....
0.4	.....	.....	(165)	(238)	(330)	(446)	(545)	.....
	.....	.....	−142.0	−123.8	−104.7	− 86.1	− 67.6	.....
0.6	.....	.....	(180)	(264)	(370)	(505)	.....	.....
	.....	.....	−140.9	−122.0	−102.7	− 83.6	.....	.....
0.8	.....	.....	(186)	(270)	(380)	(520)	.....	.....
	.....	.....	−138.1	−119.0	− 99.5	− 80.0	.....	.....

*—Figures in parentheses indicate bubble-point pressures in pounds per square inch, absolute.

TABLE IX
PARTIAL ENTHALPIES OF BUTANE IN LIQUID PHASE

Weight Fraction n-Butane	Pressure lb./sq. in. Absolute	70° F.	100° F.	130° F.	160° F.	190° F.	220° F.	250° F.
				Pure n-Butane				
		(31.3)*	(51.3)	(80.8)	(121.0)	(174.4)	(243.5)	(330.4)
1.0	Bu. P.	−158.8	−141.2	−122.5	−102.7	− 81.6	− 59.4	− 36.3
	100	−158.6	−141.0	−122.5	.....	.....	.....	.....
	200	−158.4	−140.8	−122.1	−102.5	− 81.5	.....	.....
	400	−158.1	−140.4	−121.6	−102.1	− 81.3	− 59.5	− 36.5
	600	−157.7	−140.0	−121.1	−101.8	− 81.1	− 59.5	− 37.0
	800	−157.3	−139.5	−120.7	−101.5	− 81.0	− 59.6	− 37.5
	1000	−156.9	−139.1	−120.2	−101.0	− 80.7	− 59.7	− 38.0
	1250	−156.4	−138.3	−119.8	−100.7	− 80.7	− 60.0	− 38.8
	1500	−155.7	−137.9	−119.3	−100.4	− 80.6	− 60.2	− 39.4
	1750	−155.1	−137.4	−118.8	−100.0	− 80.4	− 60.3	− 39.8
	2000	−154.4	−136.7	−118.3	− 99.2	− 80.2	− 60.3	− 40.1
	2500	−153.1	−135.5	−117.2	− 98.7	− 79.5	− 60.1	− 40.5
	3000	−151.7	−134.2	−116.0	− 97.7	− 78.8	− 59.8	− 40.6
				Methane-n-Butane System				
		(819)	(900)	(980)	(1048)	(1111)	(1167)	(1173)
0.9	Bu. P.	−111	−126	−126	−123	−122	−109	− 82
	1000	−110.3	−125.6	−125.9	.....	.....	.....	.....
	1250	−109.4	−124.8	−124.9	−121.9	−120.9	−108.1	− 80.7
	1500	−108.5	−124.0	−124.0	−120.8	−119.5	−105.7	− 76.8
	1750	−107.7	−123.2	−123.3	−120.1	−118.4	−103.8	− 73.5
	2000	−106.8	−122.5	−122.7	−119.4	−117.6	−102.3	− 70.7
	2500	−105.1	−121.1	−121.5	−118.3	−116.4	− 99.9	− 66.4
	3000	−103.4	−119.7	−120.3	−117.0	−115.4	− 97.9	− 63.4
		(1393)	(1485)	(1565)	(1611)	(1620)	.....	.....
0.8	Bu. P.	−132	−115	−103	−112	−149	.....	.....
	1500	−130.8	−114.8	.....	.....	.....	.....	.....
	1750	−128.3	−112.3	−101.1	−110.6	−147.6	.....	.....
	2000	−126.2	−110.2	− 99.1	−108.5	−145.5	.....	.....
	2500	−122.9	−106.9	− 95.8	−105.4	−142.4	.....	.....
	3000	−120.5	−104.6	− 93.5	−103.0	−140.2	.....	.....
		(1745)	(1796)	.....	.....	.....	.....	.....
0.7	Bu. P.	−141	−110	.....	.....	.....	.....	.....
	1750	−141.0	.....	.....	.....	.....	.....	.....
	2000	−137.5	−107.1	.....	.....	.....	.....	.....
	2500	−132.4	−102.0	.....	.....	.....	.....	.....
	3000	−128.8	− 98.3	.....	.....	.....	.....	.....

*—Figures in parentheses indicate bubble-point pressures in pounds per square inch, absolute.

TABLE X
PARTIAL ENTHALPIES OF N-PENTANE IN LIQUID PHASE

Weight Fraction n-Pentane	Pressure lb./sq. in. Absolute	70° F.	100° F.	130° F.	160° F.	190° F.	220° F.	250° F.
				Pure n-Pentane				
			(15.7)*	(25.6)	(42.3)	(64.9)	(94.9)	(133.2)
1.0	Bu. P.	.....	−140.8	−124.2	−107.1	− 89.6	− 71.3	− 52.2
	100	.....	−140.6	−124.1	−107.0	− 89.5	− 71.3	.....
	200	.....	−140.4	−123.9	−106.8	− 89.4	− 71.3	− 52.1
	400	.....	−140.0	−123.4	−106.5	− 98.3	− 71.2	− 52.2
	600	.....	−139.5	−122.9	−106.1	− 89.0	− 71.0	− 52.3
	800	.....	−139.0	−122.4	−105.8	− 88.7	− 70.8	− 52.2
	1000	.....	−138.6	−122.0	−105.4	− 88.3	− 70.6	− 52.2
	1250	.....	−138.0	−121.5	−104.8	− 87.9	− 70.2	− 51.9
	1500	.....	−137.3	−121.0	−104.3	− 87.5	− 69.8	− 51.6
	1750	.....	−136.7	−120.4	−103.7	− 87.0	− 69.4	− 51.3
	2000	.....	−136.0	−119.8	−103.2	− 86.3	− 69.0	− 50.9
	2500	.....	−134.7	−118.6	−102.0	− 85.2	− 68.0	− 50.2
	3000	.....	−133.4	−117.2	−100.7	− 84.0	− 66.9	− 49.3
				Methane-n-Pentane System				
			(1093)	(1165)	(1230)	(1282)	(1316)	(1331)
0.9	Bu. P.	.....	−102.5	−100.7	− 98.1	− 89.7	− 72.7	− 50.0
	1250	.....	−102.1	−100.4	− 98.0	.....	.....	.....
	1500	.....	−101.4	− 99.6	− 97.0	− 88.5	− 71.3	− 48.2
	1750	.....	−100.7	− 98.8	− 96.1	− 87.4	− 69.9	− 46.3
	2000	.....	−100.0	− 98.0	− 95.2	− 86.4	− 68.8	− 45.0
	2500	.....	− 98.6	− 96.5	− 93.5	− 84.6	− 66.9	− 43.2
	3000	.....	− 97.2	− 94.9	− 91.8	− 82.9	− 65.4	− 41.8
			(1840)	(1910)	(1951)	(1962)	(1934)	.....
0.8	Bu. P.	.....	−110.3	−113.1	−112.9	−104.6	− 85.7	.....
	2000	.....	−108.8	−112.3	−112.5	−104.3	− 85.1	.....
	2500	.....	−105.1	−108.8	−109.1	−100.9	− 81.2	.....
	3000	.....	−102.2	−106.2	−106.6	− 98.4	− 78.5	.....
			(2211)	(2250)	(2240)	(2168)	.....	.....
0.7	Bu. P.	.....	−119.0	−122.0	−122.1	−111.1	.....	.....
	2500	.....	−117.0	−120.1	−120.0	−107.9	.....	.....
	3000	.....	−114.1	−116.9	−116.5	−104.1	.....	.....

*—Figures in parentheses indicate bubble-point pressures in pounds per square inch, absolute.

TABLE XI
ENTHALPIES OF SUBSTANCES OF HIGHER MOLECULAR WEIGHT

Weight Fraction	Pressure lb./sq. in. Absolute	70° F.	100° F.	130° F.	160° F.	190° F.	220° F.	250° F.
				Crystal Oil*				
1.0	0	4.4	17.9	32.1	46.8	62.2	78.1	.....
	100	4.6	18.2	32.4	47.1	62.4	78.4	.....
	200	4.9	18.4	32.6	47.4	62.7	78.6	.....
	400	5.4	19.0	33.2	47.9	63.2	79.2	.....
	600	5.9	19.5	33.7	48.4	63.8	79.8	.....
	800	6.4	20.0	34.2	49.0	64.3	80.3	.....
	1000	7.0	20.6	34.7	49.5	64.9	80.8	.....
	1250	7.6	21.2	35.4	50.2	65.5	81.5	.....
	1500	8.3	21.9	36.0	50.8	66.2	82.2	.....
	1750	8.9	22.5	36.7	51.5	66.9	82.9	.....
	2000	9.6	23.2	37.4	52.2	67.6	83.6	.....
	2500	10.9	24.5	38.7	53.5	69.0	85.0	.....
	3000	12.2	25.8	40.0	54.8	70.3	86.4	.....
				Kettleman Hills Crude Oil*				
1.0	100	.....	20.8	36.8	53.6	71.3	89.8	.....
	200	.....	21.0	37.1	53.9	71.6	90.0	.....
	400	.....	21.6	37.6	54.4	72.1	90.5	.....
	600	.....	22.1	38.2	55.0	72.6	91.0	.....
	800	.....	22.6	38.7	55.5	73.1	91.6	.....
	1000	.....	23.2	39.2	56.0	73.6	92.1	.....
	1250	.....	23.8	39.9	56.7	74.3	92.7	.....
	1500	.....	24.5	40.5	57.3	74.9	93.3	.....
	1750	.....	25.2	41.2	58.0	75.6	94.0	.....
	2000	.....	25.8	41.8	58.6	76.2	94.6	.....
	2500	.....	27.1	43.2	59.9	77.5	95.9	.....
	3000	.....	28.4	44.5	61.2	78.8	97.2	.....

*—Based upon a datum value of zero for the enthalpy of the saturated liquid at 60° F.

				Dominguez Crude Oil*				
		(10.2)†	(17)	(26)	(35)	(45)	(58)	.....
1.0	Bu. P.	4.8	17.9	32.2	47.0	62.5	78.7	.....
	100	4.6	18.2	32.4	47.4	62.7	78.8	.....
	200	4.8	18.5	32.6	47.7	62.5	79.0	.....
	400	5.4	19.0	33.2	47.9	63.4	79.4	.....
	600	5.9	19.5	33.6	48.4	63.9	79.9	.....
	800	6.5	20.0	34.2	48.9	64.4	80.4	.....
	1000	7.0	20.5	34.7	49.4	64.8	80.8	.....
	1250	7.7	21.2	35.4	50.1	65.5	81.4	.....
	1500	8.4	21.9	36.0	50.7	66.1	82.0	.....
	1750	9.1	22.6	36.6	51.4	66.7	82.6	.....
	2000	9.8	23.2	37.3	52.0	67.3	83.2	.....
	2500	11.2	24.6	38.6	53.3	68.6	84.4	.....
	3000	12.6	25.0	40.0	54.6	69.8	85.7	.....

*—Based upon a datum value of zero for the enthalpy of the saturated liquid at 60° F.
†—Figures in parentheses indicate bubble-point pressures in pounds per square inch, absolute.

tions are recorded in Table XIII. The equilibrium constants and molecular weights used in these calculations are also indicated.

From the state of the exit gas and liquid phases the corresponding enthalpies have been computed and are 45.7 and 34.6 B.t.u. per pound, respectively. The weight of gas leaving the separator is 32 pounds per hour while that of the liquid is 968 pounds per hour.

Under the conditions normally encountered the over-all energy balance for steady flow may be written in the following form:

$$\sum_{r=1}^{r=n} m_r \left(h_r + \frac{\mu_r^2}{2g} + H_r\right) = \mathring{W} - \mathring{Q} \quad (3)$$

In the case of the particular problem under consideration there is no work associated with the flow process between entering and exit sec-

TABLE XII
ENTHALPIES OF MIXTURES OF HYDROCARBONS

Pressure lb./sq. in. Absolute	Temperature	Component	n_K	$\overline{H}_K$ Btu./lb.	$n_K\overline{H}_K$	H Btu./lb.
		Gas Phase				
3000	70° F.	Methane	0.40	− 74.3	−29.7	
		Ethane	0.60	−132.3	−79.4	
						−109.1
1500	160° F.	Methane	0.60	25.2	15.1	
		Ethane	0.30	− 14.5	− 4.4	
		Propane	0.10	− 28.8	− 2.9	
						7.8
500	200° F.	Methane	0.45	78.5	35.3	
		Ethane	0.05	48.3	2.4	
		Propane	0.15	39.9	6.0	
		n-Butane	0.25	40.3	10.1	
		-nPentane	0.10	28.3	2.8	
						56.6
		Liquid Phase				
3000	100° F.	Methane	0.20	− 44	− 8.8	
		n-Butane	0.80	−104.6	−83.7	
						− 92.5
500	160° F.	Ethane	0.07	−114.5	− 8.0	
		Propane	0.30	−105	−31.5	
		Crystal Oil	0.63	48.7	30.7	
						− 8.8
1500	220° F.	Methane	0.02	12.1	0.2	
		Ethane	0.05	− 84	− 4.2	
		Propane	0.13	− 69	− 9.0	
		n-Butane	0.15	− 60.2	− 9.0	
		n-Pentane	0.25	− 69.8	−17.4	
		Dominguez Crude Oil	0.40	82.0	32.8	
						− 6.6

TABLE XIII
ENTHALPY CALCULATIONS FOR A STEADY-FLOW PROCESS
Pressure 1000 lb./in.² Abs.

Component	Molecular Weight	Equibrium Constant[25] 100° F.	220° F.
Methane	16.042	4.320	4.734
Propane	44.095	0.382	0.843
n-Pentane	72.147	0.0775	0.200
Crystal Oil	337	0.0000	0.000

Input Liquid
Pressure 1000 lb./in.², Temperature 100° F.

Component	n_K	$\overline{H}_K$ Btu./lb.	$n_K\overline{H}_K$
Methane*	0.030	− 28	− 0.8
Propane	0.150	−141	− 21.2
n-Pentane	0.170	−138.6	− 23.6
Crystal Oil	0.650	20.6	13.4
		Enthalpy =	− 32.2 Btu./lb.

Output Gas
Pressure 1000 lb./in.², Temperature 220° F.
Weight Fraction of the Input Liquid =0.032

Component	n_K	$\overline{H}_K$ Btu./lb.	$n_K\overline{H}_K$
Methane*	0.371	83	30.8
Propane	0.487	25	12.2
n-Pentane	0.142	19	2.7
		Enthalpy =	45.7 Btu./lb.

Output Liquid
Pressure 1000 lb./in.², Temperature 220° F.
Weight Fraction of the Input Liquid =0.968

Component	n_K	$\overline{H}_K$ Btu./lb.	$n_K\overline{H}_K$
Methane	0.019	40	0.8
Propane	0.139	− 60	− 8.3
n-Pentane	0.171	− 70.6	− 12.1
Crystal Oil	0.671	80.8	54.2
		Enthalpy =	34.6 Btu./lb.

Combined Enthalpy of Outgoing Fluids = $0.032 \times 45.7 + 0.968 \times 34.6 = 35.0$ Btu./lb.
Enthalpy Change = $35.0 - (-32.2) = 67.2$ Btu./lb.
Heat Requirements $67.2 \times 1000 = 67,200$ Btu./lb.

*—The choice of compositions for this example is not specially suited to the information available but represents a random choice thought to be of general applicability. The interpolations of the partial enthalpies of methane are subject to significant uncertainties and the particular methods employed which involved interpolation of the behavior of the methane-crystal oil, methane-butane, and methane-pentane systems undoubtedly leaves much to be desired in the way of accuracy. However, the entire contribution of methane is usually small and therefore this uncertainty exerts small effect upon the accuracy of the over-all calculations.

tions, the changes in elevation are small, and the velocities of the fluids entering and leaving the separator contribute only in a minor way to the energy relationships. Under these circumstances Equation 3 may be simplified to read

$$\sum_{r=1}^{r=n} \overset{o}{m}_r H_r = -\overset{o}{Q} \qquad (4)$$

The application of Equation 4 to the information recorded in the parts of Table XIII which have been discussed yields a value of 67.2 B.t.u. per pound of entering fluid as the heat requirement for the heater operating under the conditions stipulated in the example. This corresponds to a total of 67,200 B.t.u. per hour for operation at a flow rate of 1000 pounds per hour.

Nomenclature

g = acceleration resulting from gravity, 32.17 ft/sec.²

h = elevation above arbitrary datum plane, ft.

H = enthalpy (specific enthalpy) of a homogeneous phase, Btu/lb.

H″ = enthalpy of two-phase mixt., Btu/lb.

$\overline{H}$ = partial enthalpy of a component in a mixture, Btu/lb.

$\overset{o}{m}_r$ = weight rate of flow across a section r, lb/sec. (Positive when entering the system, negative when leaving).

n = total no. of comp. in system,

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or of streams entering or leaving a flow system.

n_g = weight fraction which is gaseous.

n_k = weight fraction of component k in a mixture.

n_l = weight fraction which is liquid.

$\overset{o}{Q}$ = rate of energy transfer from surroundings by thermal means, between sections, Btu/sec.

Σ = summation.

u = mean linear velocity normal to a section; ft/sec.

$\overset{o}{W}$ = rate of energy transfer to surroundings by mechanical means, between sections, Btu/sec.

Subscripts.

g refers to a gas phase.

k refers to any component in a mixture.

l refers to a liquid phase.

r refers to a section across a flowing stream.

*The values presented in Table I to V are reproduced from a paper by Sage, Olds, and Lacey entitled, "The Enthalpy of Gaseous Hydrocarbon Mixtures", API Drilling and Production Practice, 1942.

These values are reproduced from a paper by Sage and Olds, entitled "Applications of Thermodynamics to Multicomponent Systems" Industrial and Engineering Chemistry **34, 526 (1942).

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C.N.G.A. December Meeting Topic To Be Centrifugal Compressors

Do centrifugal compressors have applications in oil-industry processes? California Natural Gasoline Association members and their friends will be given the answer to this question at the December 5 meeting of the Association at Rio Hondo Golf Club. The speaker will be Mr. T. R. Foster, Manager of Centrifugal Compressor Sales for Clark Bros. Co.

Mr. Foster is eminently qualified to discuss the subject.

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California Oil World's Monthly Summary

DEVELOPMENT—PRODUCTION—SUPPLY & DEMAND
PACIFIC COAST TERRITORY

TABLE I—CALIFORNIA DEVELOPMENT—PRODUCTION

	SEPTEMBER, 1946 DEVELOPMENT				PRODUCTION	
	Active Drilling Wells	Oil Wells Completed	Initial Production B/D	Oil Wells Completed First 9 Months	Daily Average September 1946	Daily Average September 1945
SAN JOAQUIN VALLEY						
Ant Hill	1	.....	.....	8	1,399	595
Antelope Hills	.....	.....	.....	.....	1,569	1,711
Antelope Plains	.....	.....	.....	.....	.....	.....
Arvin	.....	.....	.....	.....	24	58
Bellevue	.....	.....	.....	.....	284	667
Belridge—North	.....	.....	.....	.....	5,062	5,883
Belridge—South	3	6	113	73	10,233	12,338
Blackwell's Corner	3	.....	.....	3	210	157
Brundage	.....	.....	.....	.....	.....	.....
Buena Vista Hills	2	.....	.....	17	38,811	45,090
Burrel	.....	.....	.....	.....	10	16
Canal	.....	.....	.....	.....	912	3,552
Canfield-Gosford	.....	.....	.....	.....	91	206
Canfield Ranch	.....	.....	.....	.....	28	26
Coalinga—East	.....	.....	.....	10	16,577	18,325
Coalinga—Nose	1	.....	.....	2	55,022	55,397
Coalinga—West	1	.....	.....	2	6,871	7,758
Coles Levee—North	2	1	932	7	15,801	19,694
Coles Levee—South	1	.....	.....	1	.....	2,292
Cymric	10	11	1,116	72	10,221	.....
Edison	1	1	248	68	14,478	7,173
Elk Hills	4	1	33	14	7,614	14,730
Fruitvale	.....	.....	.....	.....	7,194	8,396
Greeley	.....	.....	.....	4	10,848	14,311
Helm	.....	2	333	23	4,226	3,485
Jacalitos	1	.....	.....	8	4,087	3,671
Kern Front	2	1	68	21	12,370	12,721
Kern River	3	2	25	15	9,753	9,661
Kettleman North Dome	2	2	1,012	18	37,287	38,531
Lanare	.....	1	217	16	2,398	835
Lost Hills	3	3	101	17	3,610	3,247
McClung	.....	.....	.....	.....	30	30
McKittrick	1	1	17	5	4,575	5,965
Midway-Sunset	2	1	245	18	35,531	39,029
Mountain View	7	3	319	10	4,769	2,860
Mount Poso	.....	1	49	14	15,853	17,995
Paloma	11	1	610	16	6,805	3,073
Pleasant Valley	.....	.....	.....	2	3,464	3,615
Pyramid Hills	.....	.....	.....	1	317	341
Race Track	2	1	201	9	1,673	1,138
Raisin City	.....	.....	.....	5	2,787	3,196
Rio Bravo	.....	.....	.....	.....	13,064	16,157
Riverdale	.....	.....	.....	7	4,551	4,002
Rosedale Ranch	.....	.....	.....	.....	140	129
Round Mountain	2	1	87	6	8,563	9,786
Salt Creek	3	3	652	9	1,668	.....
Santiago	1	2	1,234	21	6,174	476
Sheep Springs	.....	.....	.....	3	536	598
Strand—East	.....	.....	.....	.....	563	639
Strand—West	.....	.....	.....	.....	2,026	1,581
Tejon	4	4	423	30	1,784	607
Ten Section	1	.....	.....	.....	8,935	10,096
Union Avenue	.....	.....	.....	.....	389	159
Wasco	.....	.....	.....	.....	750	1,078
Wheeler Ridge	.....	.....	.....	.....	227	236
Miscellaneous	1	.....	.....	3	94	36
TOTAL SAN JOAQUIN VALLEY	75	49	8,035	558	402,258	413,348
COASTAL AREA						
Aliso Canyon	3	.....	.....	6	3,014	3,303
Bradley Canyon	.....	.....	.....	.....	.....	31
Capitan	.....	.....	.....	6	3,519	2,312
Del Valle—East	.....	1	495	1	1,736	2,526
Del Valle—West	.....	.....	.....	2	3,462	3,906
Elwood	1	1	100	7	7,017	5,893
Gato Ridge	.....	.....	.....	4	3,905	4,323
Hasley Canyon	.....	.....	.....	.....	.....	.....
Newhall-Potrero	2	1	98	7	5,929	5,426
Oak Canyon	.....	.....	.....	1	1,684	1,907
Oxnard	1	.....	.....	.....	884	1,271
Padre Canyon	1	.....	.....	2	2,421	2,098
Ramona	6	2	188	19	1,459	331
Rincon	1	.....	.....	.....	4,346	4,570

MONTHLY SUMMARY—Continued	SEPTEMBER, 1946 DEVELOPMENT				PRODUCTION	
	Active Drilling Wells	Oil Wells Completed	Initial Production B/D	Oil Wells Completed First 9 Months	Daily Average September 1946	Daily Average September 1945
San Miguelito	2	1	1,950	6	5,398	5,092
Santa Barbara	.....	.....	.....	.....	57	88
Santa Maria	10	3	716	17	13,168	14,181
Santa Maria Valley	2	4	244	37	31,096	37,714
Summerland	.....	.....	.....	.....	.....	.....
Ventura Avenue	9	1	891	32	47,526	46,142
Ventura-Newhall	6	4	390	19	7,341	5,637
Watsonville	.....	.....	.....	.....	.....	25
Zaca Creek	.....	.....	.....	.....	249	239
Miscellaneous	.....	.....	.....	.....	.....	.....
TOTAL COASTAL DISTRICT	44	18	5,072	166	144,211	147,015
LOS ANGELES BASIN						
Alondra (formerly Gardena—West)	.....	.....	.....	1	554	.....
Brea-Olinda	1	2	1,561	5	10,886	11,273
Buena Park	.....	.....	.....	2	53	91
Coyote—East	1	2	65	7	5,015	5,034
Coyote—West	2	1	214	7	14,783	15,764
Dominguez	2	.....	.....	8	15,796	18,451
East Los Angeles	2	.....	.....	4	770	.....
El Segundo	.....	.....	.....	1	551	796
Huntington Beach	6	4	732	36	46,776	47,297
Hyperion	1	.....	.....	.....	195	.....
Inglewood	.....	.....	.....	.....	12,532	15,134
La Mirada	1	.....	.....	1	43	.....
Lawndale	.....	.....	.....	.....	21	19
Leffingwell	.....	.....	.....	1	18	.....
Long Beach	.....	.....	.....	1	24,080	26,493
Los Angeles-Salt Lake	.....	.....	.....	.....	477	488
Montebello	.....	.....	.....	2	8,161	9,797
Newport-Costa Mesa	2	6	1,042	50	6,223	2,074
Playa Del Rey	.....	.....	.....	.....	2,245	2,415
Potrero	.....	.....	.....	1	736	1,061
Richfield	.....	.....	.....	6	7,436	7,516
Rosecrans	.....	.....	.....	3	4,973	5,577
Sansinena	.....	.....	.....	.....	68	116
Santa Fe Springs	.....	.....	.....	.....	16,356	16,887
Seal Beach	2	.....	.....	16	10,271	9,589
Torrance	.....	3	149	16	8,408	8,776
Turnbull Canyon	.....	.....	.....	.....	134	165
Whittier	.....	.....	.....	.....	963	1,001
Wilmington	16	15	8,220	144	121,691	100,182
Yorba Linda	.....	.....	.....	.....	.....	10
Miscellaneous	.....	.....	.....	.....	.....	.....
TOTAL LOS ANGELES BASIN	36	33	11,983	312	320,215	306,006
EXPLORATORY						
Outpost Wells	30	.....	.....	.....	.....	.....
Wildcats	28	.....	.....	.....	.....	.....
Gas Wells	5	6	Gas	51	.....	.....
TOTAL CALIFORNIA	218	106	25,090	1,328*	866,684	863,369

*—Includes gas wells completed and 241 drilling wells abandoned.

TABLE II—SUPPLY AND DEMAND FOR PETROLEUM PRODUCTS
PACIFIC COAST TERRITORY
DATA FOR SEPTEMBER OF EACH YEAR

	Sept. 1941	Sept. 1942	Sept. 1943	Sept. 1944	Sept. 1945	Sept. 1946
RAW MATERIAL—B/D						
1. Crude Oil Produced—California	646,771	726,401	780,790	887,723	866,369	866,684
2. Crude Oil from outside 5 Western States	2,629	3,832	5,277	4,710	5,231	3,249
3. Natural Gasoline Produced	39,000	37,000	40,000	43,000	44,000	43,000
SUPPLY OF FINISHED PRODUCTS						
ALL SOURCES—B/D						
4. Natural Gas., L.P.G. and Condensate	3,233	5,466	5,233	9,900	9,067	14,434
5. Gasoline and Naphtha Distillates	256,034	258,300	266,834	327,100	333,333	320,800
6. Kerosene and Kerosene Distillates	4,734	5,933	8,633	9,367	4,867	14,233
7. Lubricating Oils, etc.	10,033	11,666	7,700	10,667	15,733	14,467
8. Gas Oil and Diesel Oil	66,633	74,200	61,000	71,067	60,466	109,667
9. Fuel Oil Residuum	288,400	393,133	440,000	421,567	443,233	375,467
10. Asphalt and Road Oils	35,433	45,500	29,200	34,667	26,967	30,100
11. Coke and Other Finished Products	4,733	1,167	500	2,666	2,767	6,100
12. Other Unfinished Oils	(2,865)	(1,433)	(10,167)	(2,567)	(767)	(4,533)
13. Refinery Shortage and Gas	25,033	31,168	38,268	49,400	41,133	35,299
14. Crude Oil (Net)	5,367	(46,734)	(3,366)	31,066	6,933	23,033
15. TOTAL SUPPLY	696,768	778,366	843,835	964,900	943,732	939,067
16 TOTAL DEMAND	703,634	752,967	991,801	901,800	953,899	860,132
17. DIFFERENCE	(6,866)	25,399	(147,966)	63,100	(10,167)	78,935
18. Stocks on hand End of each month (Total Bbls.)	142,644,000	131,550,000	114,684,000	92,851,000	76,553,000	87,576,000

Alignment Chart for Solving Problems Involving the Relative Position of Geologic Markers

By L. R. MERRYMAN

The accompanying alignment chart has been designed to determine the relative position of two geologic markers, the angle of dip, or the distance between contours.

While the chart can be used to solve other variations of problems involving the relative position of markers the three basic problems are described below:

EXAMPLE NO. 1. The dip angle and the distance between wells are known. It is desired to know the vertical difference between a known point on the up dip well and the down dip well. It must, of course, be assumed the slope remains constant between wells. The problem is illustrated on Fig. No. 1 and its solution is shown on Fig. No. 2. The procedure is as follows:

Place a straight edge at 10° (dip angle) on the right hand scale and 660 feet (distance between wells) on the left hand scale. The answer, 116 feet, is read on the center scale.

EXAMPLE NO. 2. The vertical difference and the distance between wells are known. It is desired to know the dip angle. Fig. No. 1 can be again used for the problem. The solution shown on Fig. No. 2 is as follows:

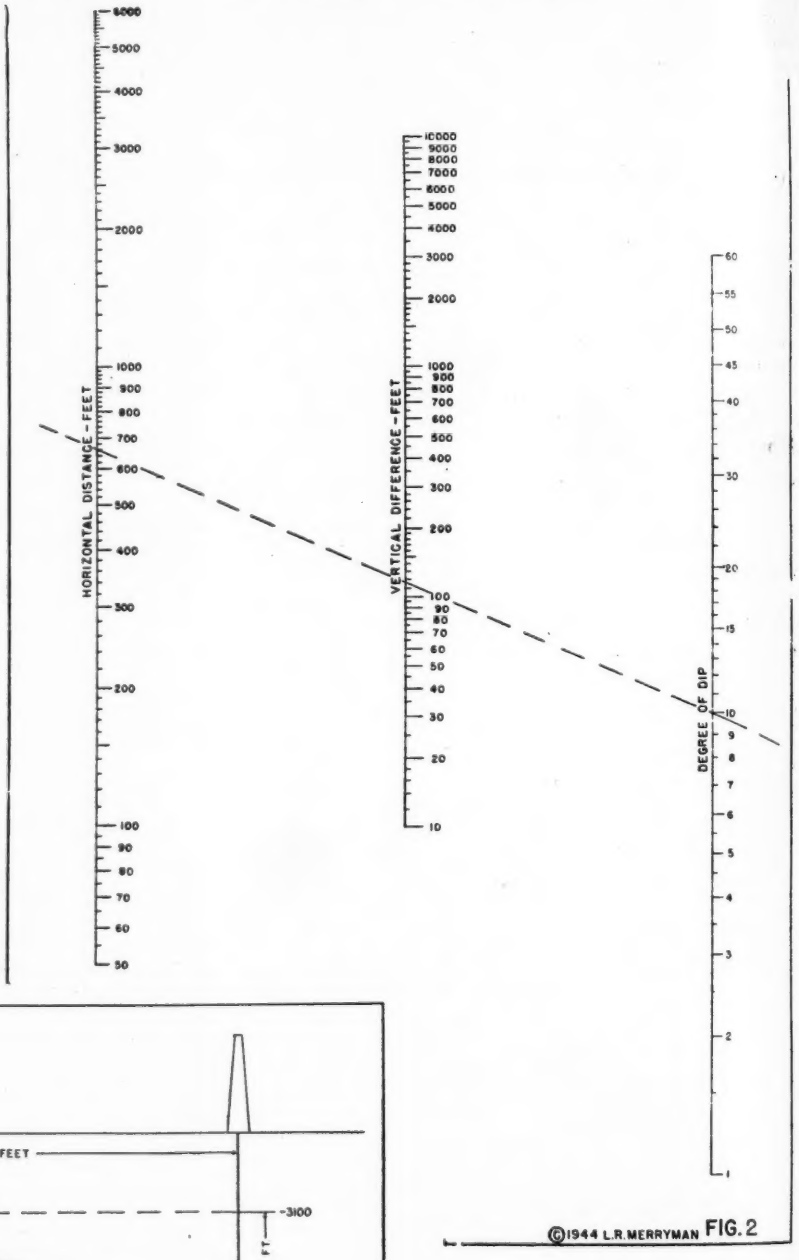


FIG. 2

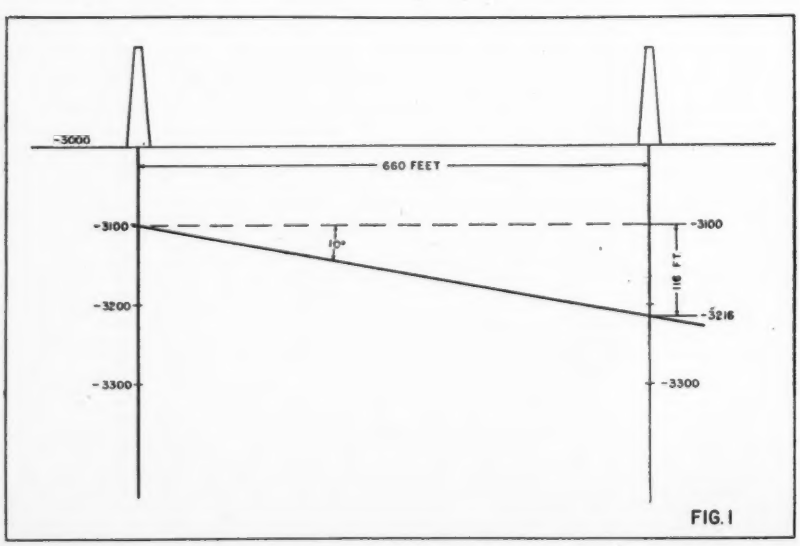


FIG. 1

Place a straight edge at the distance between wells on the left hand scale and at the vertical difference on the center scale. The answer 10°, is read on the right hand scale.

EXAMPLE NO. 3. A contour map with a 100 foot contour interval is

being made. It is known that the dip angle at a point is 15°. It is desired to know what the distance should be to the next interval line. The solution is shown on Fig. No. 3 as follows:

A straight edge is placed at the contour interval, 100 foot, on the center scale and at the degree of dip on the right hand scale. The answer, 373 feet, is read on the left hand scale. This distance is then measured on the map with a scale.

The problems described above must be solved repeatedly in the construction of subsurface exhibits and the engineer or geologist can save many hours of routine computation by its use.

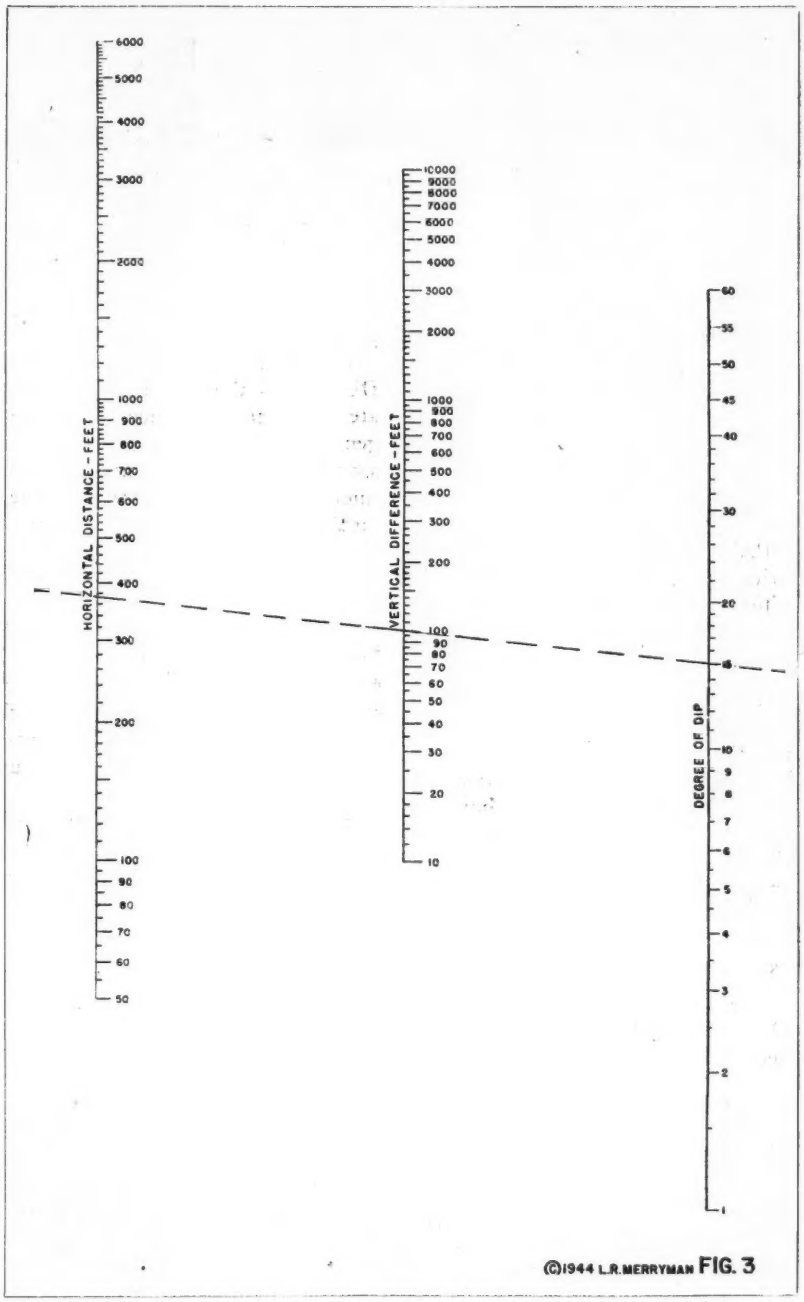


FIG. 3

Houdry Engineer to Prepare German Reports

Dr. Warren F. Faragher of the Houdry Process Corporation has been selected by the Office of Technical Services, Technical Industrial Intelligence Division, as the U. S. Government's representative to go to Germany to supervise the preparation by Germans of final reports on the German petroleum processes. Arthur V. Danner, executive vice-president of the Corporation, made this announcement as Dr. Faragher departed for Europe recently.

The purpose of Dr. Faragher's mission will be to complete the collection of the German information on the programs surveyed by the U. S. Technical Oil Mission which was sent to Germany by the Petroleum Administration for War in 1945 and to have German reports prepared thereon. This group, of which Dr. Faragher was a member, followed advance troop elements to investigate German manufacturing methods of hydrogenation, catalytic cracking, hydroforming, alkylation, polymerization, Fischer-Tropsch, and other processes. At that time, the chaos resulting from the war and the displacement of German technical personnel left unanswered many of the questions concerning German methods. In the past year, however, many of the missing technicians and numerous documents have been located and from them Dr. Faragher expects to obtain the data necessary for the completion of the reports.

Dr. Faragher has been associated with Houdry Process Corporation since its formation in 1931. A former Assistant Director of Mellon Institute of Industrial Research, Dr. Faragher also has served as instructor at the University of Pittsburgh, where he instituted and conducted the first petroleum engineering course in the school's history. Prior to joining Houdry, Dr. Faragher acquired a broad experience in the petroleum field.

Average depth of oil wells drilled in the United States in 1945 was the deepest in history—3,469 ft.—or 7.3 per cent deeper than in 1944.

More than 100 million dollars is being spent to expand the nation's facilities for the manufacture of plastic materials, many of which are derived from petroleum.

Kern County OIL NEWS

UPPING PRICE FEVER is registered on every crude producing agenda. AND THE BOYS on the retail line are waiting for a compensating gas price rise at pumps. Like the majority of Americans, Kern is no exception as regards the lack of fear to be on their own in free markets since OPA's demise. A period of higher prices will be sure to follow, but after first upward trends are over even oilmen predict generally reasonable levels.

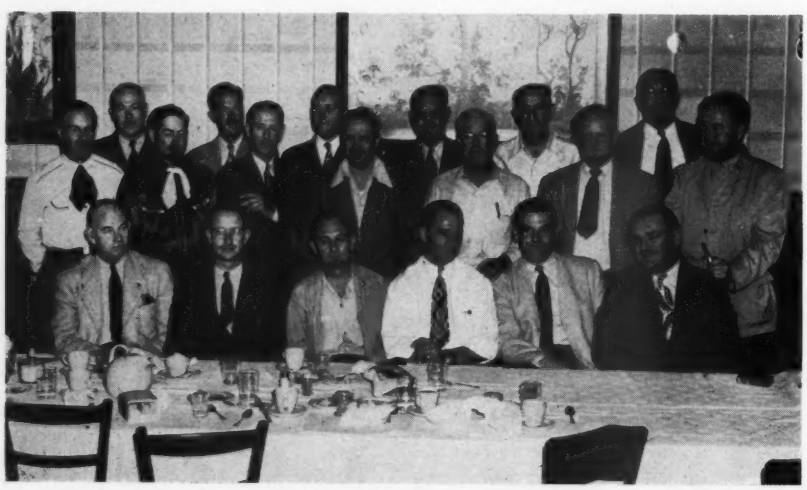
TO THE COUNTY OF KERN has come more news in oil but every month brings news unusual as usual in the Golden Empire. Di Giorgio's Western Gulf has given hope to continued "schist" production that claims to establish one more new area. Bolsa Chica's offset plans have confirmed the economics for more buying orders at some stock exchanges.

WORLD'S RECORD DRILLING depths once more have easily been broken but oil displays on coring racks forecast no broken depth producing finals.

FROM INCEPTION TO PRODUCTION the M.E.R.'s still operate and most producers are still gentlemen, but slight differences in some interpretation slants will soon smooth out the contests when further "gives and takes" are rationalized by subsequent parleys now in embryo.

THE D/B average totals are up in Kern as old demands still call for fluid. Demand for fuels will also help the winter months' returns. Armed forces too, still reach for more Kern crudes as termination of the calendar year chalks up increased returns.

SO ALL IN ALL, the oil economy of Kern still seems to have just everything. And of course, this must include those "taxes" too. In some discussion quarters, this item is a timely "cuss", but action by so many groups resolve in placing all protests to individuals, as best complaintants to take action for next budget year.

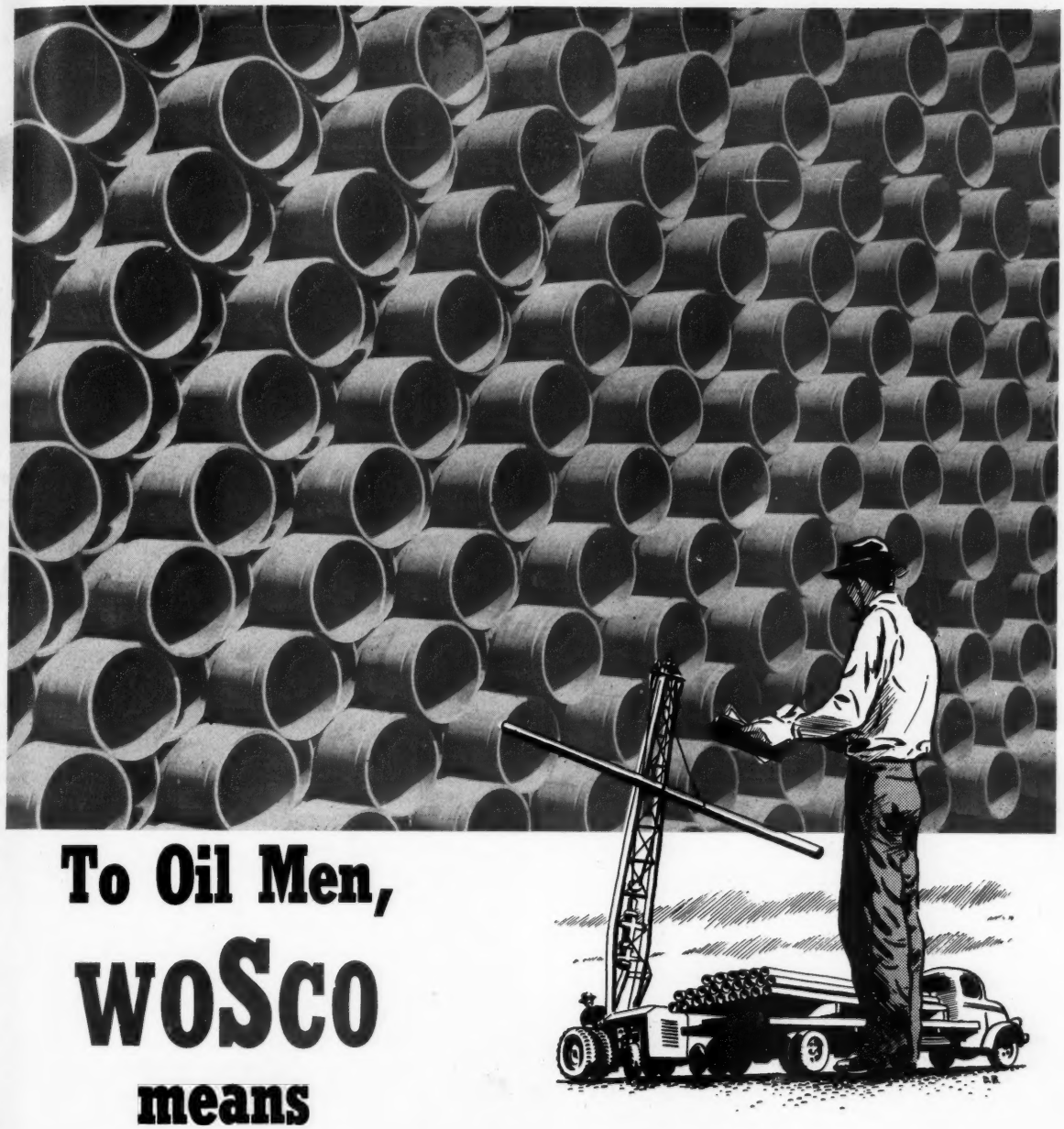


TAFT'S OILDORADOANS: (Seated) C. T. Murray, E. J. Lindstrom, R. F. Casey, H. Knost, J. K. Pruitt and Norman Crouse. (Standing) J. B. Spellacy, Don Urner, L. E. Causey, T. R. Scott, Mayor John Perryman, Herb Benno, Walter Keene, Supervisor A. W. Noon, Beecher Rintoul, C. A. Williams, M. E. Faulkner, Pres. C. of C.; Dick White and Vern McLeod (Manager C. of C.). They make oil and oil makes them.

AT STOCKDALE IN ITS GUARDED shelter, the greens and fairways were a sight. The "19 Holers" were a crew and mostly foresomes spudded in with greenbacks dangling from their pockets at the "sinks". This story had some mighty coverage and none participating has yet dared to ripen up his memory, so postmortems seem to be so ever green. As some must lead and some must follow, so some must win and some must lose. The "COW" was conscious of the tournament and human interest had a living record of its own for most oilwig posterity.

TO EACH HIS OWN has come promotion in more categories than one for one Big Ten's family group. For instance, in the case of Standard its postwar dreams for geologywigs have just about come true. Four of its men have now made recent news and Kern has claimed the spotlight. George Cunningham, Owen Haynes, George Knox and Bill Barbat.

GEORGE CUNNINGHAM who used to be here, is general manager, as you may know, of Standard's new Department of Exploration. For twelve long years he was assistant geologist. OWEN HAYNES is now the assistant general manager of the D. of E. Then GEORGE KNOX was made District Superintendent with offices here; but the loss most keenly felt by laymen is BILL BARBAT of Taft who went to San Francisco to be assistant chief geologist. Bill was a "planner" in more ways than one, and did a bang up job on Kern County Planning Commission which when its master plan is further executed will serve to avoid duplication of tax fund spending. At the same time it will be a fine pattern for orderly community public works development. And so the story goes with interest in every stanza.



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WESTERN OILFIELDS SUPPLY COMPANY — WOSCO

H. W. (HERM) WEDDLE, chairman of the San Joaquin Geological Society is at this writing making plans for the annual meeting December 10, with Tom Woodward at Taft as vice chairman in charge of programming the event.

FOR THAT INFORMATION of yours: Kern's Edison Basement Schist Fields-not-too-much-Incorporated is a baby weighing 3 and 1/3 million barrels production, and continuing to be almost fat and sassy with new wells to the pipelines from new punches on almost every week end's oil report. JACK BEACH now keeps a diary of it just in case some "crude" reporter wants to know.

INTEREST IS HIGH in Pacific Western, National Royalties No. 1 hard out by old Lost Hills, as records break for deep drilling in California. The civic conscious boys are already proof reading their brochures on the wonderful county of Kern. Even the name "Miramonte Area" adds poetic nonsense to the superlative attributes of grammar dessertation. Luster to the landscape is also much enhanced.

MASCOT'S LLOYD WILLIAMSON: First of the calendar year Lloyd Williamson, well known leader of civic affairs as well as in oil production, was made President of Mascot Oil Company. Formerly with California Star, first at Fellows and then at Los Angeles, Williamson for a quarter of a century was a known quantity of energy and management. In leadership Lloyd Williamson is still remembered by Kern County civic groups for whom he made a lasting contribution by his fairness and understanding of both human and economic resources.

PAUL J. HOWARD'S taxpert-ing paper as revealed in a reported news item from PJ sources has caused a riot in the office of your scribe and more information has been volunteered exemplifying good research, restoring Public Relations.

IN HONOR OF HIS VISION that inspired great resources to human and commercial values from the natural resource "Oil" . . . hizzoner Ex-Mayor Harry A. Hopkins relived old 1910 for OILDORADO DAYS at Taft, for he was honorary mayor of the celebration. And Harry really looked the same, as there is a time when one can stop the birthday clock and just refuse to grey his temples any further.

TAFT'S "OILDORADO," formerly "Black Gold Days" now identifying Huntington Beach, originally and more recently again, was a colorful homecoming event. In addition the six-mile long parade and the most excellent horse show vied with state honors as celebrations for postwar performances might appear to the connoisseur of public events.

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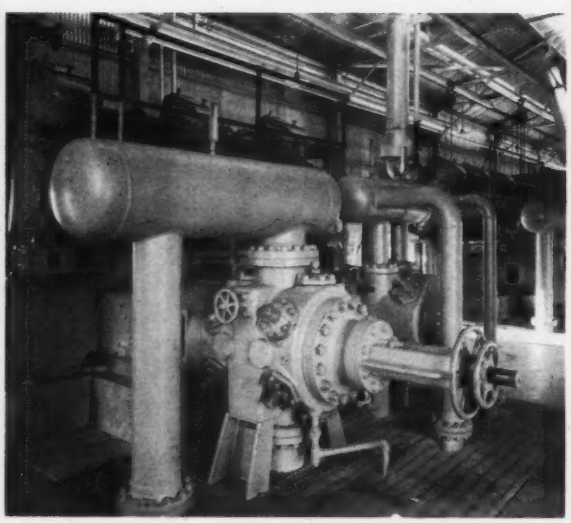

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ONE SAD NOTE that marred the friendly recollection of those who make the human values stand out in an endless search and quest for happiness, was the passing of grand uncle JOE McDONALD.

AND SO WE WRITE the line we dreaded to do for so long. For many times just recently, this sturdy pioneer (at three score years plus seventeen) had slipped through the tackle of the "grim reaper" who hovers over accidents and health impairments at this age: "as it must to men on earth, the visit of the swish and rustle from the ageless sythe" . . . last month had come to even Joe McDonald." The man was loved by everyone. His memory will live in perpetuation by survivors who mourn him most because Joe's loving kindness toward his fellowmen has been so thoughtfully handed down.

BARNEY L. BARNES of Oildale last, but Texas first, has lived in Kern all the best days of his life. A likeable oil man in Texas and a fine construction engineer in California, Barney earned his spurs in many a political sphere of influence. Recently the people of big District Three in Kern have given him a four year mandate as their County Supervisor.

SPEAKING OF TEXAS, even competitors of retail service stations confirm in many quarters, that from here to Florida, if you see one Texaco you see two and maybe three, all at about the same time. Coverage and service are equally as good.

SUBSEQUENT TO A PROPER INTERVAL, reporters, operators, editors and scribes who take long trips across the country feel incumbent upon themselves to tell the travel tale. As time goes on the anxiety to do so wears, and soon retires. Your note toting, synthetic skidding, traveling guide to **Utopian** free economies, demurs before he tries to tell you how not to be like anything he saw along 9000 miles. Repairs to everything laid waste not by war but by shortages will make the most important industry in itself; come the releases of so many goods and services before the surplus buying power is soon dissipated by so many frills, as much

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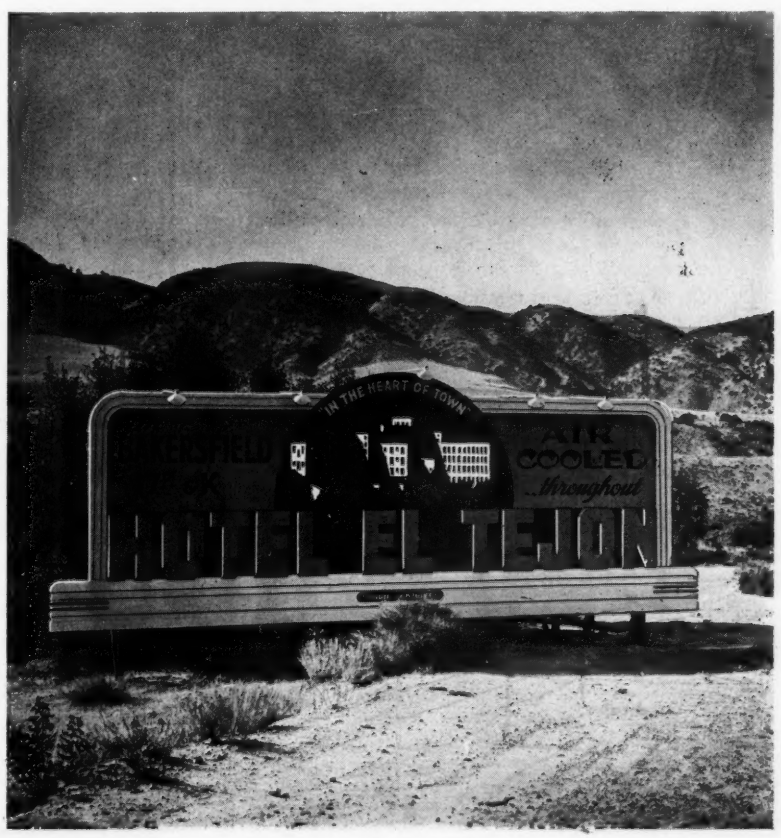

too non-productive, as the swords of war.

A WIFE OF ONE GEOLOGIST here had taught the third grade long enough and went to a Jersey city where she could change the accent of thirdgraders to Western vernacular. The spring had come and such progress in the school room was to be tested out of doors on objects of enchantment on the budding trees. Correcting little George who pointed excitingly at a "boid," the child retorting earnestly then said, "that's funny—it choips like a boid."

AT A RICHFIELD SERVICE STATION here we spied Frank Kelley "filling up" on his own stuff. Among things he attested Richfield gas and said the business was the most flourishing and lucrative here. He spoke of postwar plans perfecting "repower" a word that's new to even Richfield not to mention its salesmen like Kelley and his many clients. Adding "zip" to motors was claimed by Richfield's chief clerk Martin Struebing now at Oak street near the overpass. He also said that C. W. Wetteroth in charge of sales for Richfield territory here had added zip in more ways than one since May the fourth when he accelerated station cash registers.

SAM SELF WAS WAITING for the rain to go away and worrying about the price of soap. He told us how he used to sell cement and later got to selling specialty goods and services for the industry's production wheels. In jovial conversation he talked of wells and oilcats, Louisiana and things. We met Ward Kelley and Roy Spig who like Sam Self and use his wares. If one would get the lowdown and knowhow combined to find the shape of things in oil, these men can hand it out in first class information style.

TAFT CHAPTER API programs ahead in famous style with not a wasted meeting ever on subjects ranging from "Tehachapi Tunnel" to "Central Valley Project." The recent meeting was a scene of anxious members listening to the story on Central Valley Water. Usually water troubles with oilmen create a bad desire to even talk about it, but when their hopes arrive to settle down to earth and own a piece of it, their human resources are enhanced in Kern when water flows off Whitney to their rancho level. So Roland Curran gave a treatise and a "paper" as they call it on Central Valley Water. Keller Grigsby, Vice, charge of program, and A. B. Newby, So. Cal. Gas Co., Chairman, introduced the speaker who is Secretary to the CVP Association. Curran was a little apprehensive lest the members had their minds on making duck ponds from the run off from canals.

THE FOLLOWING OFFICERS were elected at the API San Joaquin Valley Chapter Taft meeting: Keller Grigsby, The Norwalk Co., Chairman; T. H. Wallace, Western Gulf Oil Co., First Vice President and D. G. Dingman, General Petroleum Corp., 2nd Vice President.

KERN'S COUNTY CAPITAL is most like Lake Charles in deep South's Louisiana. On Supply Row the same insignia and signs of trademarks dot the streets on either side. The men who man the shops are experts and precision workmanship excels in allied industry,

Putting a bobbin of yarn into upright rope machine is Jim Poulidis, a Tubbs rope maker for nearly two decades.

It requires the finest fiber to make the best rope—but the fiber alone is not enough.

It requires the "know how" of skilled rope makers to properly blend this fiber and follow it through every stage of production to the finished rope product.

For nearly a century this combination of men and rope has been a heritage of the Tubbs mills. Here old timers —many descendants of several generations of rope makers—work side by side with newer hands to make a rope product that may proudly bear the Tubbs trademark.

When you specify rope—specify Tubbs. It is your guarantee of greater rope dependability, greater rope value.

TUBBS EXTRA SUPERIOR MANILA CORDAGE COMPANY

Look for this trademark when the finest Manila fiber is once more available.

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surpass the quality of big city car repairs even as it does right here.

BUT A SIGN IN THE BARBER SHOP at L.C. is necessary only there. It reads, "No profanity or politics, please." It's a good idea. Another idea that's not so good in nearby environs some voters who cast their ballots that day were certain they had to vote just what they indicated at the registration for the primary. When at this time the opportunity afforded was made easy by remembering just one party. In Texas it was different. They believe in two party systems very distinctly, but they never forget their own party either.

IN CENTRAL NORTHERN FLORIDA some Kernexperts are helping "Humble Oil" to punch deep holes in wildcat territory. The leases there run miles in radius and every native as well as absentee landlord now shops for many tips from Californians. Don't ever think a little love is lost between the Miracle City of Miami and the city of the Angels. He who spans this chasm of redoubt can skip and hop with ease from Mars to Jupiter. Best way to get along down there is to brag about their home cooking, their blondes and snowwhite sand and weather. Keep up the Play factor, not the Stay factor. There is a difference between playing and staying in any place. They think every Californian is a contributor to the Don Thomas (All Year Club) million dollar program to keep population away from the Everglade state. So tell them that we spend this necessarily to get them out here after they see Florida first. Most sensitive subjects: potatoes, manufacturing and humidity between June and December.

MOST HAZARDOUS THING IN Kern oilfields used to be flying tools before the cat on almost every drilling rig. Worst worry warting hazard in Miami are the cocoanuts that fall from trees that could lower over derricks. But nature has been kind and cocoanuts only fall between 2 and 4 a.m. The best things (if they are free,) then surely must be cocoanuts for early morning transgressors pick their weight in palmtree fruit within an easy fortnight. Kern oilworkers in Florida at tower changing time on the graveyard shifts fear cocoanuts more than lightning there, or earthquakes here.

LAST TIME WE SAW CHARLEY MANLEY of Oilfields Construction Company he was "dickering" with the state to sell his "chicken ranch" frontage on U. S. 99 so the new freeway would not pass him by. Only difference between negotiations at this period was about $50,000.00 dollars, but it looked like Charley was going to compromise for a cigar, if the highway could be lowered to platform level for easy loading onto trucks that pass that way enroute to blackgold fields.

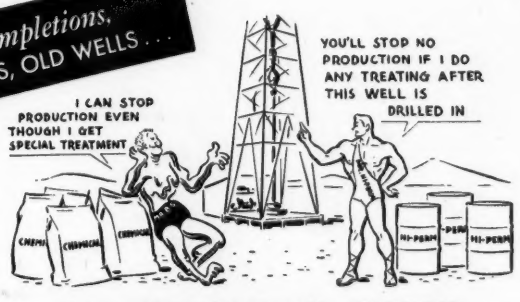
WESTERN OILFIELDS SUPPLY COMPANY'S Charles P. Lake, who knows how to live and does it, is always the same to employee personnel, customer and friend. However, when your operator conked his desk with a cocoanut he had no choice in sharing its hard shell. So rumor has it that he'll try his hand in sculptoring and let it poise before his other models before the mantle piece.

SIGNS OF TIMES revealed themselves when Owen "Valve" Johnson's office manager Bray went limiting for squirrels up Greenhorn way. He bent his fender riding out the chase on two pet squirrels that game laws warned to run the first time in a score of years.

OTHER SIGNS THAT THE OILDORADO in Taft had ended were when C. E. (Curley) Emmons shaved his sideburns off the reservation for his temples.

MOST OILFOLKS just like other folks get tired of eating any place. But most of all most folks that gad about get tired the most just eating every place. So all who like fresh fruit and vegetables on all the days around the year should never even gripe at hash at "Ellery's Eatery." Why it's so much like fun to eat at Hotel El Tejon just now that most Kern travellers would pay amusement tax (despite Ernie's opposition to it) for even a bowl of Rowland's soup.

New Completions, REDRILLS, OLD WELLS . . .


I CAN STOP PRODUCTION EVEN THOUGH I GET SPECIAL TREATMENT
YOU'LL STOP NO PRODUCTION IF I DO ANY TREATING AFTER THIS WELL IS DRILLED IN
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FLUOR HOSTS C. N. G. A. AGAIN

The annual Fluor cocktail party has been a feature of the fall C.N.G.A. dinner for so many years that it just wouldn't seem like a C.N.G.A. meeting without it.

This year, as usual, Fluor played host and any member of the Association who missed the party can be regretting it until some time in October, 1947.

These candid camera shots of oil men at work on a problem pertaining to the absorption of liquefied carbohydrates indicate the enthusiasm with which the research was conducted.

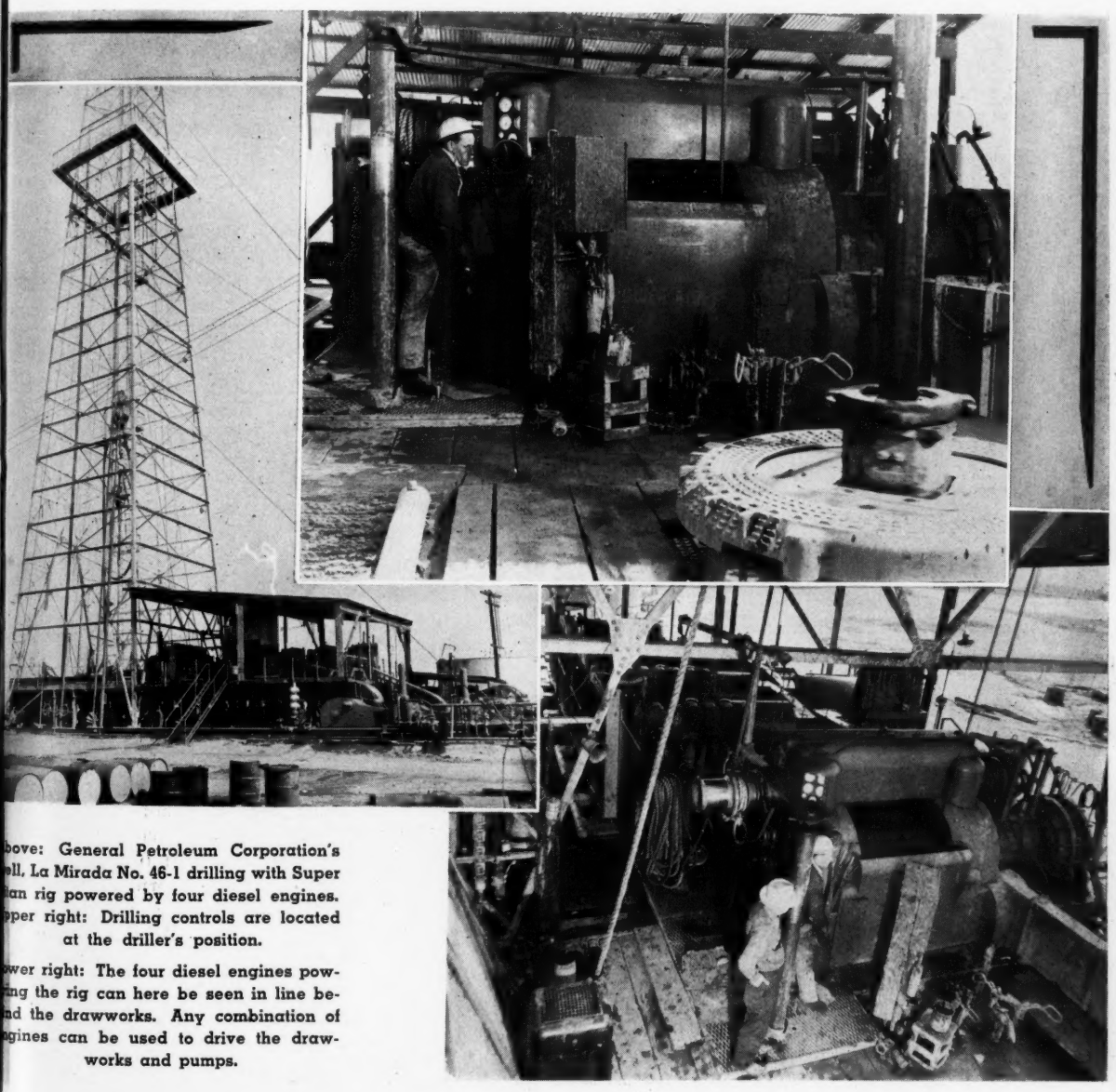
A canvass of those who participated indicates the results were highly successful.

Large Power Rig Drills California Well

For drilling its well La Mirada 46-1 in the La Mirada area lying between Santa Fe Springs and Coyote, General Petroleum Corporation installed one of the largest power rigs yet constructed. Known as the Wilson Super Titan "66", this rig is of the same design as the one of smaller capacity that was used to drill to a depth of 15,195 feet, the record for power driven rigs. The La Mirada well is being drilled by Loffland Brothers, contractors.

As shown in the illustrations, the rig is powered by four Model LP-600 Cummins diesel engines. Provisions are made for compounding all engines either forward to the drawworks or to the rear for drive to the mud pumps. Any combinations of engines desired can be used to drive the drawworks or pumps. This assembly is designed to drill to a depth of 18,000 feet with 4-inch drill pipe and is capable of going proportionately deeper with smaller drill pipe.

The drum is 66 inches in diameter and the brake rings are 63 inches outside diameter. The rig is equipped with an internal, self-energizing, shoe-type clutch and is provided with circulating water cooling in the space between the brake ring and the clutch ring. Among other features is a vacuum-controlled, chain-drive transmission with transmission speed lock and shift lock. The rig is mounted on two-unit main skids.



Above: General Petroleum Corporation's well, La Mirada No. 46-1 drilling with Super Titan rig powered by four diesel engines. Upper right: Drilling controls are located at the driller's position.

Lower right: The four diesel engines powering the rig can here be seen in line behind the drawworks. Any combination of engines can be used to drive the drawworks and pumps.

Dwindling Gas Reserves, Soaring Population Trend, Made Texas to California Gas Line Necessary, CNGA Told

A natural gas deficiency of some 276 million cubic feet per day was indicated for Southern California during the winter 1948-49 by a forecast of local gas supply vs. demand for peak day conditions shown the California Natural Gasoline Association at its November 7, 1946 meeting by Roy M. Bauer, Gas Supply Supervisor for Southern California Gas Company and Southern Counties Gas Company.

As early as the fall of 1943, Bauer stated, the gas companies had concluded that if such a crisis were to be averted it was necessary that they seek and obtain without delay a major out-of-state source of gas. California natural gas productible reserves, he said, had reached a peak in 1945 at about 11 trillion cubic feet. He predicted that the oil-well gas available to the Southern group of gas companies from California sources would decline from the peak of 525 million cubic feet per day reached in July 1945 to 410 million cubic feet per day at the end of 1946, and to about 250 million cubic feet per day by 1951. For this same period, he predicted a growth in population and in industrial activity for Southern California which will add an average of 27,000 new meters annually to the gas companies' systems.

As a result of these trends, he predicted that by 1949 the gas available from California sources would just equal the firm (domestic and essential industrial) demand. Thereafter, this supply would be insufficient.

A survey of the known adequate reserves within economic range of pipeline transportation quickly narrowed down to the Houghton-Panhandle fields and those of the so-called Permian Basin. Extended negotiations were carried on with several producers who had leaseholds in these fields, and finally, last summer, a contract was entered into with the El Paso Natural Gas Co. to deliver gas obtained from both these sources at Blythe, on the Arizona-California border.

The maximum contracted volumes to be delivered are 125 million cubic feet per day for the first year (1947), 175 million cubic feet per day the second, third, and fourth years, and 305 million cubic feet per day for the fifth and succeeding years of the thirty year period. Experts who have made a comprehensive study of the fields are satisfied that the reserves and contract rights supporting the project insure that the draft requirements can be met.

Linking California's own rich oil fields with those of Texas is a measure calculated to insure a long time supply of gas for Southern California. California fields will, of course, continue to be the primary source of supply.

To complete the project, Bauer stated, it will be necessary to install approximately 1212 miles of main pipe line. The line will consist of 24", 26", and 30" diameter pipe, and will extend from Dumas in the Texas Panhandle to Los Angeles. The total cost of the project, including compressor stations, will be approximately $70,000,000. Of this, $54,000,000 will be the cost of El Paso's portion and $16,225,000 the cost of the California companies' portion.

For the final stage of the project, the El Paso Natural Gas Co. will have six field compressor stations and six booster stations with an aggregate rated horsepower of 130,000. Booster station spacing will average about 100 miles, compression ratios will range from 1.52 to 1.6, and pipeline operating pressures at station outlets will be 780 to 820 psi. The maximum design stress in the pipe wall is 36,600 psi.

The California companies' 214-mile connecting pipeline from the Arizona-California border to Santa Fe Springs will be 30" in diameter. A main line compressor station of 10,000 horsepower at Blythe, pressure-limiting stations, lateral lines, and appurtenant facilities will complete the installation.

This part of the project has three unusual features. These are: (1) its diameter—30" O.D.—which makes it the largest sized transmission line in the world; (2) the use of pressure-limiting stations and; (3) a design which makes available approximately 52 million cubic feet of storage at roughly 1/6 the cost of conventional gas holder storage.

Some of the considerations which led to the use of the 30" diameter pipe were the following: (1) a reduction in compressor horsepower, resulting in an annual fuel saving of $64,000; (2) the possibility of later increasing the capacity of the line to 400 million cubic feet per day.

The use of pressure-limiting stations will effect a saving of some 7,400 tons of steel and about $600,000 in capital. Each pressure-limiting station will be located at a mainline valve station and will consist of several gas pressure-reducing regulators operating in parallel in a by-pass around the mainline valve. During periods of low flow, the mainline valve in each station will close automatically. All gas will pass through the regulators, which will limit the downstream pressure to the designed maximum.

When the rate of flow increases beyond the combined capacity of the regulators, the mainline valves will open automatically. Relief valves will be installed at each station as secondary protection for the downstream section. Without the use of the pressure-limiting stations it would have been necessary to design the entire California section of the line to withstand the 810 psi discharge pressure of the Blythe compressor station.

To insure delivery of 305 million cubic feet of gas per day at Santa Fe Springs at a pressure of 250 psi, the pressure required at the discharge of the Blythe compressor station is 675 psi. By designing the line for a somewhat higher pressure, and adding 2700 horsepower in the Blythe station to compress gas to 810 psi instead of 675 psi, storage capacity, in the form of line pack, was obtained at a relatively low incremental cost, and with no impairment of the required 24-hour deliverability of the line. During the unpacking period, gas can be withdrawn at a sustained rate of 500 million cubic feet per day for two hours.

With Drilling Contractors

Santa Maria Drilling Co., formerly known as Kern Drilling Co., has added another producing well to its list of completions by finishing Morton & Sons' Irvine project at Huntington Beach. It is drilling for the same company, Holtz No. 1 in the beach area. The Rincon wildcat, sponsored by Honolulu Oil and Signal Oil & Gas, also is a Santa Maria drilling assignment. President E. R. Morris and Secretary-Treasurer, A. J. Simonis make headquarters in Long Beach.

Two of the most interesting test wells in the San Joaquin Valley are digging under contract to Rocky Mountain Drilling Co. They are Richfield's Berry No. 1 at South Belridge, in which interest is shared by Richfield with a number of other companies, and Standard's Kettleman Hills Middle Dome test. Other Rocky Mountain contract jobs include Richfield's U. P. Unit No. 3 at East Los Angeles, and Shell's Dozier-Pressley No. 1 at Rio Vista.

Directors of M. Thornbury, Inc., recently organized to engage in contract drilling, are W. H. (Bill) Geis, F. G. Bruce and William Thornbury.

Richards & Rowan, Ventura contractor, has rig up for Republic Operator, Inc., an important test near Castaic, north of the Del Valle field.

Karl L. and J. K. Kellogg of K. K. Kellogg & Sons, and Ralph Marshall of Drilling & Exploration Co. were among California contractors attending the 26th annual convention of the American Petroleum Institute in Chicago.

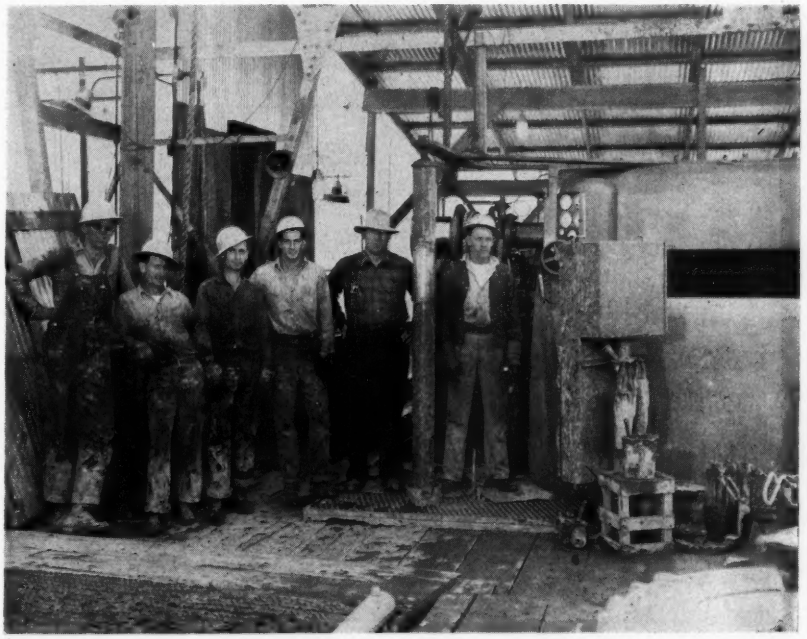
With practically all the major crude oil purchasing companies in the Mid-Continent, Rocky Mountain, Middle Western and Southern areas inaugurating price increases of 10 cents a barrel, California members of the contract drilling fraternity anticipate similar action shortly by major purchasers in this state.

Higher postings are bound to stimulate new drilling in all California areas and the consequent benefit to contractors should be considerable. For months there have been rumors of an impending increase in the price paid for crude. Apparently these reports were well-founded.

Among current Hayes & Sprague, Inc., jobs are Seaboard's Mission Land No. 8-1 in the Newhall area, and Richfield's Boyle Comm. No. 33 at East Los Angeles. San Joaquin Drilling Co. has completed Pacific Western's Francis Brix Comm. No. 1 in the Lanare area.

Pacific American Oil Co., Long Beach contractor, has completed H. S. Kohlbush, Carson No. 23 in the Torrance field. Fowler Drilling Co. has the contract for redrilling Catalina Oil Co., Port No. 2 and No. 3 in the Wilmington field. O'Kane & Brain is rigging up to drill No. W-150 for Long Beach Oil Development Co. at Long Beach Harbor. Standard's Newson Comm. No. 1 near the Santa Fe Springs field is an H. S. Tenny job. Clyde Hall has successfully completed Corey No. 53 at Mountain View for L. S. Gilmour & Associates.

The McFann Drilling Co. of Long Beach in cooperation with Severns Drilling Co. is drilling Portals No. 33-3 for the British-American Oil Company at Race Track Hill. The surface pipe was set on November 17th.



Pictured above is the crew of the General Petroleum Corp.'s well, La Mirada 46-1, which is being drilled by Loffland Bros. Left to right: O. H. Funk, John McGearey, J. D. Yoho, J. W. Perkins, Jr., Paul A. Dahlitz, Tool Pusher, W. J. Matter, driller.

Field Development

PREPARED FROM CALIFORNIA OIL WORLD NEWS SERVICE

Los Angeles Basin

Devils Canyon Wildcat Scene

A new wildcat test is ready to start work in the Devils Canyon area near Castaic. The well, known as Devils Canyon No. 1, is sponsored by Universal Consolidated Oil Co. in Sec. 27-5n-17w. The Texas Co. and Standard Oil Co. participate in the test by "dry-hole" contributions. Southern California Petroleum Corp. is an acreage contributor.

Involved in the play is a total of 660 acres, considered likely to benefit primarily from a commercial well.

Beach City Still Active

Hiawatha Exploration Co. is preparing to grade ground for its Atha No. 4 in Sec. 13-6s-11w in the Huntington Beach area. Eagle Oil & Ref. Co. has location staked for Eagle No. 12 in Sec. 12-6s-11w. Fred Davies is planning a new well between Mortin & Sons' Irvine producer and the initial Hiawatha well. Southern Belle Oil Co. has redrilled Rex No. 12 to 7926 ft. and is fishing tubing.

Amerada Petroleum Corp. last was reported concentrating on a squeeze job on its Anaheim Sugar No. 64-7 in Sec. 7-6s-10w, with plug at 5580 ft. Barnhart-Morrow Cons. has completed its Alford No. 2 in Sec. 18, initially flowing 890 barrels of oil a day from 3785 ft. Location for No. 3 has been made 820 ft. south and 810 ft. east of the west quarter

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corner of the section. Knowledge gained in drilling the new producer, may induce the company to attempt to work over its No. 1, which was completed for an unsatisfactory field.

Meantime, Mortin & Sons is drilling ahead and spot coring below 4100 ft. with Holtz No. 7-1 in Sec. 7. M. R. & M. Syndicate has abandoned at 9752 ft. its Crew Comm. No. 1 in Sec. 32-5s-10w. Warren L. Meeker & Russell D. Garner are grading drill site for Mountain View No. 1 in Sec. 18-6s-10w. Water witch is being run in Signal Pet. Co. of Calif.'s Deeble No. 1 in Sec. 13, after salt water was swabbed. Total depth is 4845 ft.

Verdoo Test Getting Pipe

Exploratory operations of Grayco Oil Co. in the Chino area of San Bernardino County have taken an interesting turn. The well, Mahla No. 1 in Sec. 13-3s-8w, is ready to run casing to approximately 3000 ft., and test open hole to bottom at 4170 ft. The company reported poker chip shale with sand was encountered at three intervals, below the 3000-ft mark. The reported thickness of each interval was given as 150 ft., 130 ft. and 70 ft. President of the company is J. P. (Bill) Gray. O. W. Murphy is vice president.

Gardena Area Yet Develops

H. C. Christie, individual operator, is about ready to begin work on his Johnson No. 1 explorer in Sec. 22-3s-14w in the Gardena area. British-American Oil Prod. Co. is drilling at 8202 ft. with Alondra Park No. 1 in Sec. 22-3s-14w. Bodger No. 2 is still a location. The Texas Co., Operator, Gardena Comm. No. 9-1 is making hole ahead below 8150 ft. Drill site falls in Sec. 26-3s-14w.

Elsinore Try On Schedule

In the Elsinore area of Riverside County, noted chiefly for its beautiful lake, Palomar Petroleum Co. has rigged up to start the drill in Tyrell No. 1 in Sec. 13-6s-4w.

Dominguez Yet Fishes

Union Oil Co., Hellman No. 58 in Sec. 27-3s-13w in the Dominguez area, continues to fish for drill pipe, with top at 2551 ft. Some 1237 ft. so far have been recovered. Total depth is 10,912 ft. The company has made location for Simi No. 8 in Sec. 22-3n-17w in the Simi area, Los Angeles County.

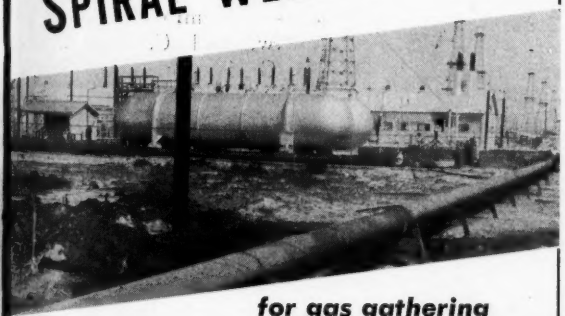
Fairview Test Stands Cemented

In the Fairview area of Orange County, Tide Water Associated Oil Co.'s Norris No. 2 in Sec 8-6s-10w is standing with casing set on plug at 3600 ft. Original bottom is 6536 ft.

Del Valle Developing

Bankline Oil Co. has foundation in for Black No. 105 in Sec. 13-4n-18w in the Del Valle area, Ventura County. Superior Oil Co. & British-American Oil Prod. Co. are drilling Black No. 6 in the section at 3571 ft.

SPIRAL WELDED PIPE



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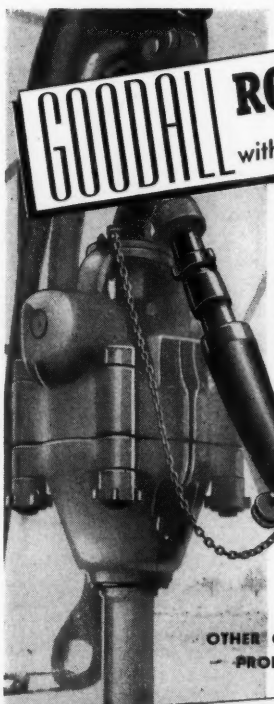

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Coastal and Northern District

Monterey County Explorers Drill

C. C. M. O. Co., San Ardo No. 6-G1, an exploratory project in the San Ardo area in Sec. 6-23s-10e, Monterey County, is drilling ahead at 7589 ft., after recovering fish and changing mud. The Texas Co.'s Aurignac No. 2 in Sec. 4 is repairing bad surface casing at 182 ft. Total depth is 1067 ft.

Ojai Test Runs Liner

Fillmore Oil Co. is ready to run liner in its Ojai No. 1 in Sec. 12-4n-22w in the Ojai area, after plugging back from 2461 ft. to 1610 ft. Casing is cemented at 1024 ft.

Rincon Try Digs On Down

In the Rincon area of the Coastal district, Honolulu Oil Corp. is making hole ahead at 4511 ft. with its Honolulu-Signal-Bates No. 1 in Sec. 36-4n-25w.

Capitan Test Sticks Pipe

Oil is being spotted in an effort to loosen drill pipe stuck in Rothschild Oil Co.'s Orella No. 1 test in Sec. 31-5n-30w in the Capitan area, Santa Barbara County. Total depth is 2753 ft., with top Vaqueros at 1526 ft.

Camarillo Job Keeps On Going

The Texas Co., Broome No. 1 explorer in Sec. 29-1n-20w in the Camarillo area is drilling on down at a depth slightly below 2950 ft.

Sisquoc Try Spot Coring

Spot coring at 6000 ft. was the last report from Union Oil Co.'s Sisquoc No. 6 in Sec. 2-8n-31w in the Sisquoc area, Santa Barbara County.

Santa Maria Adds Locations

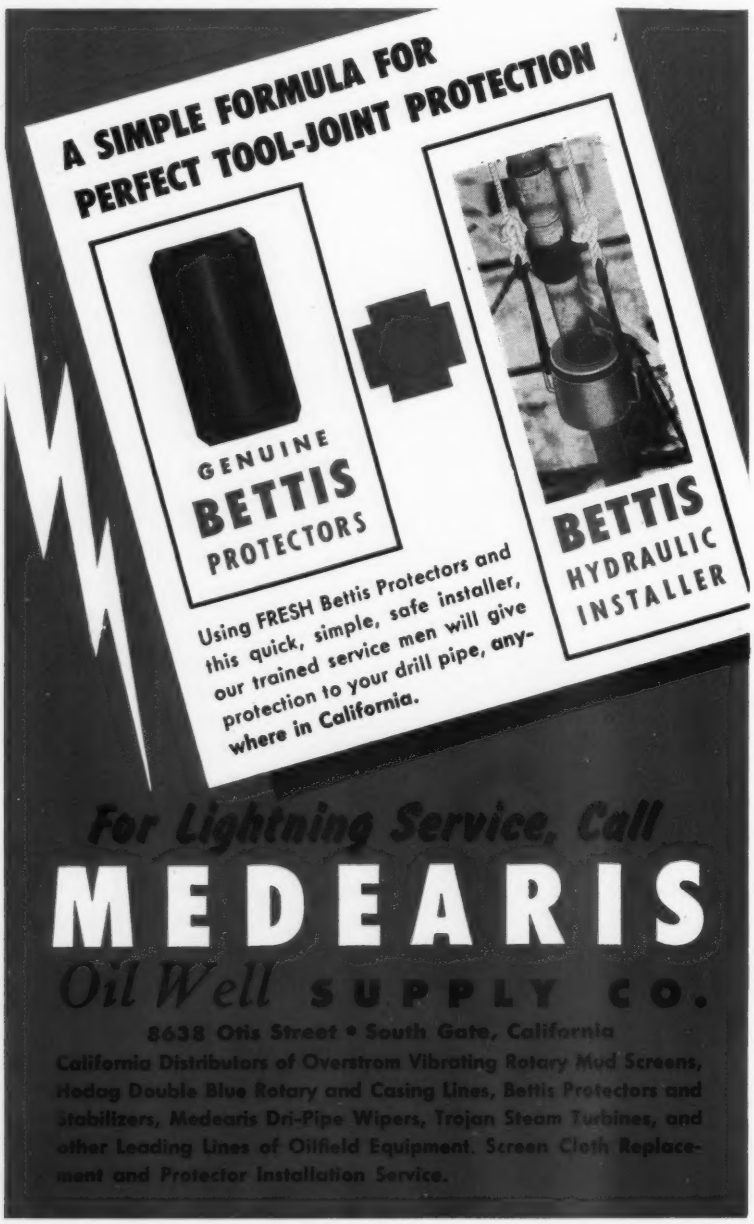
Sunray Oil Corp. has staked location for Giacomini No. 5 in Sec. 18-10n-24w, and C. E. O'Donnell Oil Co. Grace No. 3 in Sec. 21. Union Oil Co. has completed Russell-Lollier No. 7 in Sec. 20 for 8 barrels daily at 5275 ft.

Lompoc Well Flowing Oil

Union Oil Co.'s Purisima No. 2 in the Lompoc field is a new completion. It was finished at 2825 ft. for a flow of 292 barrels of 20 gravity oil a day, through a 48/64 in. orifice. The shut off was effected at 2425 ft.

Los Alamos Wildcat Idle

Torrential rains have brought about temporary suspension of Whittier Associates' Barham No. wildcat test in Sec. 11-7n-32w the Los Alamos area of Santa Barbara County. The well went 6870 ft. before plugging back 6583 ft.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San Joaquin Valley

Arvin Scores New Discovery

Western Gulf Oil Co. has confirmed discovery of a new producing area at Arvin by finishing its Di Giorgio No. 1 in Sec. 10-31s-29e, flowing at the rate of 400 barrels of 31.6 gravity oil a day, cutting 1.7 per cent through a 22/64-in. bean. Totai depth is 6163 ft., with 7-in. cemented at 5877 ft. and 357 ft. of 5-in., including perforations between 5935 ft. and 6160 ft., landed at 6161 ft. Production finds its source in fractured Schist formation.

Bolsa Chica Oil Corp., holder of acreage along the strike, is preparing to begin Di Giorgio No. 8-3 in Sec. 3-31s-29e. Other holders in the area include, Union, Texas Co., Tide Water Associated, and Universal Consolidated.

The strike has created much speculative interest in the area, which may prove to duplicate capacity for production in the fractured schist somewhat in parity with Edison, which was developed there two years ago.

Jasmine Test Grades Ground

Bandini Petroleum Co. is grading ground fo its Jasmine No. 1 in Sec. 5-25s-27e in the Jasmine area of Kern County. The area in line for interrogation has been the scene of considerable wildcatting, without notable success. Many geologists, however, view the area with favor.

Tulare Lake Well Yet Tests

Kings County Oil Co. has perforated an interval around 9700 ft. preparatory to further testing its von Glahn No. 1 in Sec. 4-23s-22e in the Tulare Lake area of Kings County. The well was drilled to a bottom of 13,213 ft. and has been testing whole by stages. On test of an interval near 10,700 ft., the well showed oil, gas and salt water.

Belridge Try Redrills On

Belridge Oil Co. is redrilling at 3,890 ft. with its No. 62-W-33, a deep test in Sec. 33-28s-21e in the South Belridge area. Original depth is 13,950 ft. In Sec. 30, Richfield Oil Corp., Berry No. 1 is fishing for drill pipe, top of which is placed at 1479 ft. Bottom hole depth is 5766 ft.

McKittrick Try Coring

On wildcat ground near the McKittrick field, General Petroleum Corp. is coring ahead at 7095 ft. with Hall-Baker No. 66-4 in Sec. 4-30s-21e, after running electric log to 7091 ft. The company has location staked for Moran No. 42-30 in Sec. 30-22s-26e in the Pixley area, Tulare County.

Kern River Test Spuds

Frank and von Glahn have spudded Elmer C., an exploratory ven-

Filter Cake has 2 faces

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As you know, one of the reasons for using mud while drilling is to build up a filter cake to protect the formation. Fine! But—if filter cake keeps drilling fluid **out** of the formation, obviously it will hold oil **in** the formation. Not so good, then! (See A.)

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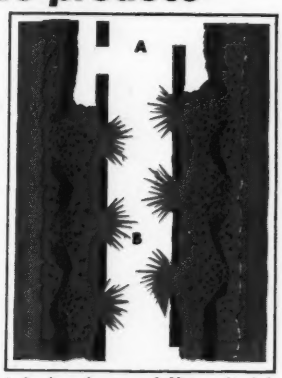

A further danger of filter cake left in the well is shown at B. Oil breaking through a few weak spots in the filter cake travels at relatively high velocity, carrying excessive sand. Perforations are being cut away, the sand body is caving: eventually this pipe will collapse.

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ture in Sec. 8-29s-28e in the Kern River area.

Buena Vista Well Testing

On formation test of the interval of 6026-6082 ft. in Continental Oil Co.'s BVA No. 1 in Sec. 8-32s-25e near Buena Vista Lake, packer failed and preparations are under way to rerun. Total depth is 10,021 ft., with plug at 6082 ft.

Arvin Try Swabbing

O. F. Darling, McNear No. 1 in Sec. 1-31s-29e in Arvin wildcat ground swabbed water with a trace of oil from perforated intervals at 2505-2530 and 2560-2580 ft. Total depth is 2600 ft., with casing cemented on bottom and tubing hung at 2560 ft.

Well Attains Record Depth

Pacific Western Oil Corp. last was reported drilling on down at 16,278 ft. with its National Royalties No. 1 test in Sec. 5-26s-22e in the Miramonte area for a new state well depth record. This 32 ft. is below the previous depth record held by a Standard project between Coles Levee and Elks Hills. The Wasco A-2 zone was topped at 16,100 ft.

Pacific Western's Francis Brix Comm. No. 1 in Sec. 16-17s-18e in the Lanare area, Fresno County, is still testing. Drilled to 7150 ft., showings were excellent.

Dominion Try Drills

Mauer & Fisher is drilling Jean No. 4 in Sec. 15-26s-28e in the Dominion area at 2249 ft. in schist. On formation test of the interval of 1697-1709 ft., salt water was recovered.

Mt. View Try Flowing Oil

L. S. Gilmour has given the finishing touches to his Corey No. 53 in Sec. 13-30s-28e on prospect ground in the Mountain View area for a flow of 135 barrels of 27.6 gravity oil daily. Total depth is 4614 ft.

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Antelope Hills Project Drills

In the Antelope Hills area of San Joaquin Valley, William L. Hernstadt continues to make hole ahead at a depth of 4858 ft. with Hernstadt No. 1 in Sec. 24-27s-19e.

Fruitvale Try Starts Drill

Jergins Oil, Operator, K.C.L. No. 68-8 in Sec. 8-29s-27e in the Fruitvale area has been spudded and is drilling at 1250 ft. Surface pipe was cemented at 493 ft.

Reed Ridge Job Drills

Avenal No. 1, sponsored by Kings Exploration Co. in Sec. 18-23s-17e in the Reef Ridge area of Kings County, is drilling steadily ahead at 3841 ft.

Edison Prospect Drills On Down

Los Nietos Co.'s Cauzza-Portals No. 1, which originated under the banner of Los Nietos Production & Refining Co., is drilling ahead at 2004 ft. Surface casing is set at 491 ft.

Jacalitos Try Pumps

Wilshire Oil Co., Inc., has completed No. 81-28E in Sec. 28-21s-15e in the Jacalitos area of Fresno County at a plugged depth of 3419 ft., pumping 85 barrels of 39.6 gravity crude oil daily. In the McKittrick area, McKittrick No. 2 in Sec. 12-30s-21e is drilling at 3576 ft.

Grapevine Try Flows Crude Oil

Reserve Oil & Gas Co., No. 1-A-21 in Sec. 21-11n-19w in the Grapevine area is adding perforated holes, after flowing oil and gas on test of perforated intervals at 5190-5240 and 5306-5345 ft. Total depth is 5383 ft., with casing cemented at 5380 ft. and tubing hung at 5170 ft.

Middle Dome Try Drilling

Standard Oil Co. is still going down with its No. 73-30V deep test in Sec. 30-23s-19e in the Middle Dome area of Kettleman Hills. Depth last reported was 11,940 ft. and drilling continuing ahead. In the Coalinga area, No. 213-35A in Sec. 35-19s-15e is drilling at 3520 ft., with the scheduled objective the Eocene formation anticipated near 6000 ft. No. W. P. 46-33W in Sec. 33-29s-21e in the Sheep Springs area is drilling at 6691 ft.

Ten Section Try Digs On

In the Ten Section area, Shell Oil Co. is prospecting ahead at 10,045 ft. with its KCL-A No. 53-30 in Sec. 30-30s-26e.

Seaboard Drills Kern Prospects

Seaboard Oil Co. is drilling Seaboard-Banning No. 3-21 in Sec. 21-28s-20e in the Bacon Hills area at 2929 ft. Seaboard Richfield No. 76-36 in Sec. 26-29s-29e in the Ant Hill area is drilling at 2187 ft.

Dixon Gas Try Making Progress

In the Dixon area, Solano County, Amerada Petroleum Corp. is drilling its gas try, known as Ernest Wineman No. 2, in Sec. 27-6n-2e at 1068 ft.

Buttes Test Fishes Liner

Liner is being fished preparatory to deepening Buttes Oilfields, Inc., Buttes No. 7 in Sec. 3-15n-1e in the Marysville Buttes area of Sutter County.

Yolo Test Rigging Up

In the Courtland area of Yolo County, General Petroleum Corp. is rigging derrick for Gallenkamp No. 1 in Sec. 10-6n-3e. Llano Seco No. 1 in Sec. 33-20n-1w suspended drilling at 5456 ft.

Potrero Hills Gas Test Idle

National Investors Fund, Inc., Burke & Donohoe No. 1 in the Potrero Hills, Solano County, is idle at a depth of 2249 ft.

Kirby Hills Try Running Tubing

Following a test which blew gas at the rate of 3,250,000 cubic ft. daily, Shell Oil Co. is running tubing to complete its Wagenet No. 1 test in Sec. 24-4n-1w in the Kirby Hills, Solano County. In the Rio Vista area, Dozier-Pressley No. 1 in Sec. 16-3n-2e is conditioning mud, after running electric log. Total depth is 8025 ft. Winters Unit No. 2-1 in Sec. 18-8n-1e is still a location in the Winters area.

Petrolia Test Drilling Ahead

W. C. M. C. Oil Co., Inc., (Yatura Oil Co.) Mathew Clark No. 1, an explorer in Sec. 21-1s-2w in the Petrolia area of Humboldt County is drilling ahead at 1080 ft.

West Mountain Adds Producer

Another producing well has been added in the West Mountain area of Ventura County by Freeman Fairfield, veteran independent producer and supply man. His latest completion is Richardson No. 1 in Sec. 23-3n-21w, which is pumping 90 barrels of 20 gravity oil daily from 3090 ft. Richardson No. 2 in the section is drilling in the shallow formations.

Oxnard Well Pumping Oil

Exeter Oil Co. has successfully finished its Livingston No. 2 in Sec. 6-1n-21w in the Oxnard area at a total depth of 3073 ft. for an estimated 130 barrels of 7 gravity crude on the pump. Tar sand was topped at 2180 ft. and Volcanics at 2865 ft.

Goleta Gasser Big Producer

Pacific Lighting Corp. has finished its Miller No. 3 in Sec. 20-4n-28w in the Goleta field, Santa Barbara County, for a yield of 54,000,000 cubic feet of gas a day through a 67/64-in. bean. The well has been shut in.

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Castaic Tests Making Progress

Work has started on two tests in the Castiac area. Republic Operator, Inc., has rig up for Fee No. 1 in Sec. 13-5n-17w. Barnsdall Oil Co., meanwhile, is grading ground for Dodge No. 1 in Sec. 32-5n-16w.

Desert Wildcat Reaches 1800 Ft.

Other than the fact that Amapola Oil Corp.'s Amapola No. 1 in Sec. 6-6n-12w in the Antelope Valley area has reached 1800 ft., little is known of the explorer to date. The test has created more than ordinary interest.

Santa Fe Springs Wells Wildcatting

Near the Santa Fe Springs field, Standard Oil Co. is drilling Carmenita Comm. No. 1 in Sec. 4-3s-11w below 9800 ft. The water shut off on the 7-in. set at 9595 ft. was no good. Newsom Comm. No. 1 in Sec. 36-2s-1w is making hole at 6240 ft. The company's Stanley Comm. No. 1 in Sec. 33-4s-10w in the Garden Grove area is rigging derrick. In the El Segundo area, Six Companies Fee No. 2 has been abandoned at 707[illegible] ft. Located in Sec. 2-3s-15w, on formation test of the interval of 7000 ft. and bottom, recovery was 796 ft. of mud and salt water.

Los Angeles Jobs Continue Drilling

In the East Los Angeles area, Richfield Oil Corp. continues to drill ahead at 6810 ft. with U. P. Unit No. 3 in Sec. 16-2s-1w. Boyle Comm. No. 33-1 in Sec 31-1s-12[illegible] is redrilling at 2250 ft., after plugging back to 808 ft. from 5902 ft. for a fresh start.

Newhall Test Coring Ahead

Seaboard Oil Co. is coring at 801[illegible] ft. with Mission Land No. 8-1 in Sec. 25-3n-16w in the Newhall area. W. W. Bush Oil Co.'s Weber No. 1 in Sec. 11-3n-16w is still a location.

The most southerly production of oil in the world is on an island off the southern tip of South America belonging to Chile.

La Mirada Test Drills On Down

After a stop to run electric log and sidewall sample, General Petroleum Corp. is drilling ahead at 11,800 ft. with its La Mirada Comm. No. 46-1 in Sec. 16-3s-11w in the La Mirada area of Los Angeles County.

Richfield Well Starting Work

A. H. Bradford is ready to start work on Hartwell No. 4 in the Richfield area of Orange County, near Walnut and Jefferson Sts. West Coast Refining Co. is redrilling its Bradford No. 4.

Wilmington Well Listed

Zephyr Oil Co. is preparing to drill well No. 10 near B and Quay Sts. in the Wilmington field. Catalina Oil Co. is ready to begin redrilling Port No. 2 and No. 3.

Baldwin Hills Job Scheduled

Ronald C. Smith is rigging up to drill Smith No. 10 in the Baldwin Hills sector of the Inglewood field.

Canoga Park Acres Leased

Cleveland Oil Co. has leased 185 acres in Secs. 4, 9 and 10-1-17, five miles south of Canoga Park in San Fernando Valley. The property involved is on the Dry Gulch Ranch and surrounds the site of a well drilling for water, which encountered 30 gravity crude oil near 200 ft.

Cleveland is preparing to open up and deepen the hole for a test of the shallow formations. The ranch is owned by Frank Knapp, Jr. He plans to name the field, in the event commercial oil is developed there, in memory of Walter Knapp, his pilot son, who lost his life over Austria in 1944.

Knapp has deeded a section of the potential field to each of his four brothers—Fred, Joe, Al and Max.

Montalvo Try Fishing Bit

With bottom of the hole at a depth of 9525 ft., Standard Oil Co.'s McGrath No. 2 wildcat in Sec. 26-2n-23w in the Montalvo area, Ventura County, is fishing drill collar and bit.

San Emigdio Try Finishes

After redrilling to 3210 ft., and swabbing oil at the rate of 8 barrels daily, Western Gulf Oil Co., is placing on the pump its San Emigdio No. 4 in Sec. 19-11n-22w in the San Emigdio area. Location for No. 5 has been made in Sec. 30.

South Dome Try Gives Up

Following a final check with electric log, Tide Water Associated Oil Co. abandoned its Fee No. 65-18 in Sec. 18-25s-20e in the South Dome wildcat area of Kettleman Hills. Total depth is 4000 ft. The company also has given up its M. & S. No. 113 in Sec. 29-28s-28e in the Kern River area at a depth of 6152 ft. in granite. Midway-McKittrick No. 5-32 in Sec. 32-30s-22e is drilling at 1532 ft.

New Series of Booklets of Interest to Drillers and Production Men

PATTERSON-BALLAGH DIVISION, Byron Jackson Co., announces the publication of a series of booklets giving information, specifications, installation instructions, parts and price lists of Oil Field Specialties of their manufacture. These booklets are in addition to the 1947 General Catalog, which is now ready for distribution also.

Patterson-Ballagh's Casing Protectors and Drill Pipe Stabilizers are well known to the industry through their ability to increase safe drilling speeds and to protect equipment against damage. The items they have introduced during the past 19 years have all had the same purpose: facilitating operations through the protection of men and equipment. The new booklets and the 1947 General Catalog explain all the articles they manufacture and offer. They may be ordered by number and will be sent free of charge:

	Booklet No.
Plastic Tubing Protectors	150
Mud Guns	200
Pipe Wipers	300
Sucker Rod Wipers	310
Kelly Wipers	320
Wire Line Wipers	330
Deep Well Swabs	340
Wire Line Guides	400
Dead-Line Stabilizers	500
Traveling Block Bumpers	600
Swivel Ball Bumpers	650
Protectors, Stabilizers, Tools, and other items	General Catalog 1947

Casmalia Job Keeps Drilling

On the Goodwin property in the Casmalia area, General Petroleum Corp. continues to make steady progress with its No. 1 wildcat in Sec. 10-9n-35w, with depth of 4430 ft.

OPPORTUNITY FOR SALES ENGINEER

Salesman or manufacturers' representative calling on oil and gas producing companies, pipe line companies, and refineries in California can soon be earning $5,000 per year and more as distributor of patented Double Seal Piston Rings. Operating records and customers' statements in our files demonstrate that Double Seal Rings cut fuel costs as much as 10% and lube oil costs as much as 50% in diesel and gas engines, and substantially increase output and cut operating costs on all types of compressors and pumps. Double Seal Ring Co. has served the oil industry for 34 years, and we offer close cooperation and prompt deliveries. No investment required. We ship orders open account and credit your commission on all new and repeat business. Commissions average from $22.50 to $250.00 per sale. Please send complete description of your qualifications. Sales Director and West Coast manager will arrange interview in your city. Address Double Seal Ring Co., Box 566-C, Fort Worth 1, Texas. 5-11-20-B

FOR SALE

3000 ft. 5 9/16 Machine scarfed drill pipe. 3600 ft. 5 9/16 Drill pipe (uncut). Herley-Kelley, 1131 Pasadena Ave., Long Beach 7, Calif. Phone 6-23. tf

FOR SALE—TANK FARM

10 acre tank farm, 4 miles from Long Beach, with 9 tanks; total capacity 14,750 bbls.; has 2 truck loading racks and loading rack on Southern Pacific spur. Price $13,000. Dutch Bandringa, Broker, 741 Compton Blvd., Clearwater, telephone MEtcalf 3-2910. tf

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Personalities IN THE NEWS

Shell Announces Two Executive Changes

Two former westeners have received new vice presidential appointments in Shell Oil Company, Incorporated, according to S. Belither, executive vice president.

Norman J. McGaw

Norman J. McGaw, general vice president, New York, moves to the company's San Francisco headquarters in a similar position. McGaw is a former San Franciscan having joined Shell in 1925 as a statistician in the local office. He became assistant to the president in St. Louis in 1933 and has been a vice president of the company since 1939.

The second appointment elevates H. S. M. Burns, widely known in the industry and a former resident of the bay region, to the senior vice presidency of Shell's east of the rockies territory. He will make his headquarters in New York. Burns joined Shell more than twenty-one years ago in California as a geophysicist in the exploration department.

The American Petroleum Institute at its annual convention in Chicago elected as directors: H. D. Collier, chairman of the board, Standard Oil Co., L. L. Aubert, president of Bankline Oil Co., William M. Keck, president of Superior Oil Co., A. C. Mattei, president of Honolulu Oil Corp., Charles S. Jones, president of Richfield Oil Corp., Sam Mosher, president of Signal Oil & Gas Co., Ted Sutter, Baker Oil Tools, Inc. and A. A. Jergins, Jergins Oil Co. Jergins will complete the unexpired term of the late Dana Hogan.

Harold Taylor and Peter Lenneman, coos aboard the L. P. St. Clair, man, cooks aboard the L. P. St. gaining a wide reputation for their skill in making pictures in copper, as their seagoing hobby. They begin their operations by outlining a design on the reverse side of a copper sheet, slightly thicker than a piece of paper. They press out the portions to be in relief, then fill in the detail, while working on both sides of the copper.

Richard Fenton, executive vice president of the California Stripper Well Association, was the guest speaker at the regular dinner meeting of the Petroleum Accountants Society held at the Los Angeles Athletic Club. His topic was "Trends in Labor Relations." J. Ray Brown, Standard Oil Co. was chairman of the meeting.

After more than four and one-half years with the Navy in the Southwest Pacific, John Hurndall, widely known petroleum engineer and geologist has shed his uniform and is back in Los Angeles. Hurndall was a member of Reparations Commissioner Edwin W. Pauley's party on its tour through Japan and China.

Emsco Announces Executive Promotions

Mr. H. H. Glen, president of Emsco Derrick & Equipment C pany, announces the following ganization staff changes:

C. L. Lamkin

Mr. C. L. Lamkin, vice president has been moved from the Houst plant, where he served as plant ma ager, to the main Emsco offices Los Angeles. In his new positio Mr. Lamkin will concern himse with all phases of the compan business from the standpoint management.

Mr. Paul Courtney, former sales manager of the Houst branch, has been appointed manag of the Houston plant to succe Mr. Lamkin. His position as Hou ton sales manager has been fill by Mr. J. T. Tucker, who previous served as field service manager f the Emsco Derrick & Equipme Company in the Mid-Continent are

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Actress Bonita Granville and m tion picture executive Jack Wrathe former Texas oil man, have a nounced they will marry.

Caldwell Joins Allied Supply Company

The Allied Supply Company an-nces the appointment of Mr. ac P. Caldwell as Chemical and rosion Engineer. Mr. Caldwell graduate of Georgia Tech and had Post Graduate studies at California Institute of Technol-Since graduation he has been ged in the chemical process in-y, the last four years being on e staff of the Goodyear Rubber rve Plant at Los Angeles e, in addition to his other es, he headed the Corrosion mittee.

Isaac P. Caldwell

Mr. Caldwell has just returned om an extended visit in the East here he spent some time at the lants of The Wm. Powell Com-any, Cincinnati; Tube-Turns, Inc., ouisville, Kentucky; National ransit Pump & Machine Company, il City, Pennsylvania, and the sev-al plants of Manning, Maxwell & loore at Bridgeport, Boston and ulsa. While at these plants he miliarized himself with the latest evelopments in the manufacture of alves, fittings and engineering spe-alties, particularly those made of loy materials for corrosion service. e also spent some time in the lab-ratories of these companies famil-arizing himself with the latest ad-ances in chemical and metallurgical rocedure.

Mr. Caldwell will be available at he offices of The Allied Supply Company for consultation on corrosion problems encountered in the oil and chemical industries.

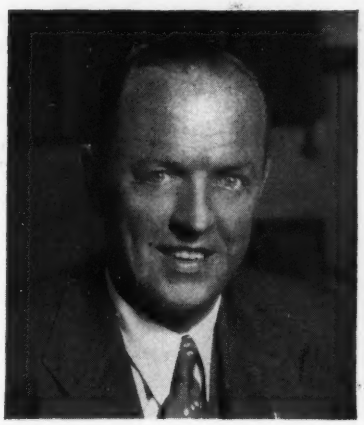
Daniel H. Hudelson assistant superintendent of stores for General Petroleum Corp., has been promoted from the rank of colonel to brigadier-general in the California National Guard. In 1941, General Hudelson was assigned to command the U. S. Commando Training Detachment in Scotland. His combat command is credited with capturing 47,000 Germans, releasing 60,000 prisoners and knocking out 117 tanks. He has won many decorations.

George J. O'Brien, vice president of Standard Oil Co. and chairman of the industrial committee of the Los Angeles Chamber of Commerce, presided at the luncheon meeting at the Ambassador Hotel, called to salute the Southern California automotive industry.

In Washington to attend the hearings of the House Naval Affairs Committee is Harry P. Stolz of the firm of Stanley & Stolz, consulting petroleum engineers and geologists of Los Angeles. Stolz, as a captain in the Naval Reserve was in charge for the Navy at Elk Hills during the war. Since release from active duty, his firm has been retained as consultants to the Navy in matters pertaining to Naval petroleum reserve No. 1. Stolz currently is chairman of the engineering committee and the engineering advisory committee appointed under the contract between the Navy and Standard.

Dick S. Heffern, a specialist in labor problems for many years, serving in that capacity with Shell Oil Co., War Labor Board and private firms, has joined Employers Industrial Relations Council of Santa Ana.

Speaking at the 26th annual convention of the American Petroleum Institute in Chicago, Reese H. Taylor, president of Union Oil Co., credited the American economic system with giving the country world leadership in oil production. Taylor's visit in Chicago was followed by a two weeks' business stay in New York City.



W. E. Sievers Opens L. A. Office

Mr. W. E. Sievers, well-known oil tool executive, announces the moving of his offices in Whittier, California to the Quinby Building, 650 South Grand Avenue, Los Angeles, California. Mr. Sievers recently resigned as Chairman of the Board of the Security Engineering Co., Inc. to devote his entire time to Sievers Industries, Inc.

Every man piloting General Petroleum Corp. planes has gained fame in military or commercial aviation or both. Pilot Arthur P. Inman and co-Pilot A. H. Carow fly the Beechcraft executive plane. Bod Dodson is Southern California pilot-salesman. E.C. Nissen and William Gooddard are the flying salesman of the Northern California division.

J. B. (Boake) Morris, administrative assistant for Shell Oil Co. in the Los Angeles office, is back at work, after a vacation of three weeks, most of which was spent fishing at Doheny Park, along the ocean near San Juan Capistrano.

The Signal Oil & Gas Co. was well represented at the annual convention of the American Petroleum Institute in Chicago. Members of the firm attending included Russ Green, Garth Young, Harry March, Ronnie Heath, Walt Greenfield, Dan Johnston and Paul Andrews.

Another prominent member of the California industry in attendance was Ed A. Cunningham, manager of public relations for Shell Oil Co.

THIS LAUGH OFF!

Caller at phone office: "These flowers are for the phone girls."

Supervisor: "Oh, thank you, sir, you flatter our service."

Caller: "Flatter nothing! I thought they were dead!"

1919--? Seems Like Yesterday

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To us at Jensen, 27 years seems like only yesterday. That's how long we've been working like the devil making units that pump oil better, last longer and cost less to operate.

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Stenog: "Howja spell 'sense'?"

Employer: "Dollars and cents, or horse sense?"

Stenog; "Well, like in 'I ain't seen him sense'."

Lovie: "Every time I kiss you it makes me a better man."

Dovie: "That's nice, but you don't have to try to get to heaven tonight, do you?"

Bob: "Do fish grow fast?"

Sam: "I'll say they do. My dad caught one and it grows six inches every time he talks about it to anyone."

His wife determined to cure him of his drunken habit. Robed in a sheet, carrying a small flashlight, she shook him energetically before she roused him.

Husband: "Whash that?"

Wife (in a sepulchral tone): "Satan."

Husband: "Shake handsh, old horse, I married your sister."

Sign in laundry window: "We do not tear your laundry with machinery. We do it carefully, by hand."

A budget is a method of worrying about money before you spend it, as well as afterwards.

College education for women is futile. If they're pretty, it's unnecessary; if they are not, it's inadequate.

"Hasn't your wife been wearing rather a strange expression lately?"

"Yes, I believe she's trying hard to look like her latest photograph."

If Eve had had a modern bathing suit she wouldn't have had to wear one of those stuffy ole fig leaves.

"Ever had any organic trouble?" asked the medical officer.

"No sir," replied the recruit. "I'm not musical."

Judging by the girls we saw in Hollywood the other day, there doesn't appear to be much slack in the seat of their slacks.

First Worker: "I hear Joe never completed his education."

Second Worker: "That's right. He lived and died a bachelor."

Officer: "How did the accident happen?"

Driver: "My wife fell asleep in the back seat."

Medic (examining patient): "Do you smoke?"

1st Sgt.: "Occasionally."

Medic: "Got a cigarette?"

"Daughter, I hope that's a good book you're reading."

"It is mother, except it's so sad at the end. The girl dies and he has to go back to his wife."

Roughneck: My wife says if I don't give up golf, she'll leave me.

Toolpusher: Hard luck, I'd say.

Roughneck: Yes, I'll miss her.

He: We sure had a good time last night for only fifteen cents.

She: Yes, and I wonder how my little brother spent it.

Three absent-minded professors were so absorbed in conversation that they didn't hear the train come in or hear the conductor's "all aboard" call until the puff of the engine attracted them. Then they all rushed for the train and two of them scrambled on it. The third looked on sheepishly.

The agent, standing near by, said, "Too bad, mister, but you shouldn't feel so badly. Two out of three made it—that's a pretty good percentage."

"Yes," sighed the professor, "but they came down to see me off!"